Aircraft WELDING

1945 EDITION

NAVY TRAINING COURSES

AIRCRAFT WELDING

PREPARED BY
STANDARDS AND CURRICULUM DIVISION
TRAINING
BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES
EDITION OF 1945

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1945

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Price, 25 cents

PREFACE

This book was written for the enlisted men of Naval Aviation. It is one of a series of books designed to give them the information to perform their aviation duties.

A knowledge of aircraft welding is of primary importance to the Aviation Metalsmith. His concern is the structural repair of Navy airplanes. In the performance of his duties, welding—and that means oxyacetylene welding in almost every case—constitutes one of the main parts of his job. He must pass qualification tests for aircraft welders put out by the Bureau of Aeronautics before assuming the responsibilities of the job.

Beginning with information on the necessary welding equipment and cautions concerning the use of it, this book steps quickly into the practical business of how to weld. Then follows discussion on the techniques for welding ferrous and nonferrous metals together with the qualification tests for aircraft welders. Also, there are sections on cutting, brazing and soldering, blacksmithing—subjects of related importance to the Aviation Metalsmith.

As one of the NAVY TRAINING COURSES, this book represents the joint endeavor of the Naval Air Technical Training Command and the Training Courses Section of the Bureau of Naval Personnel.

TABLE OF CONTENTS

AIRCRAFT WELDING

CHAPTER I

TOOLS OF THE TRADE

OXYACETYLENE WELDING

As an Aviation Metalsmith you have a critical job. You will frequently have to make repairs on airplane parts in which welding is required. And you will sleep a lot more soundly if you KNOW all of your welds are sound. It may not matter how smart the pilot of an airplane is, if some joint is weakened because of a poor weld. You carry a great deal of responsibility on your shoulders.

Welding in general is a process used for joining metal parts by either FUSION or FORGE WELDING. Both are "thermal metal joining processes"—a fancy way of saying that you apply HEAT to the metal parts you want to join. For aircraft repair, you will use only the fusion method of welding.

In fusion welding you apply heat enough to MELT the edges or surfaces of the metal so that the molten parts flow together. When it cools, you have a single, solid piece of metal.

There are two kinds of welding which depend upon fusion—GAS and ELECTRIC welding. Oxyacetylene welding is a GAS METHOD and is the one you will use as an Aviation Metalsmith.

You are going to learn how to use the welder's TOOLS to make welds in the various AIRCRAFT METALS you may encounter. And then, because a welding torch is good for several things besides welding, you will find out how to CUT metal with it, how to BRAZE and how to do HARD SOLDERING with it.

You will also find in this book a section on SOFT SOLDERING and one on FORGING. You are not expected to become a highly skilled blacksmith, but you DO have to know enough about hand forging to be able, in an emergency, to make yourself certain simple tools.

Now that you have a general idea of what's coming, how about starting at the beginning—with the oxyacetylene welder's outfit.

For your purposes, gas welding means applying heat by burning a properly balanced mixture of oxygen and acetylene as it flows from the tip of a welding torch—the oxyactylene method.

The temperature of the oxyacetylene flame at the tip-point is approximately 6,300° F. (Fahrenheit).

THE WELDING OUTFIT

The oxyacetylene equipment may be either PORTABLE or STATIONARY. The portable apparatus is fastened on a hand truck and can be pushed around to the place where it is needed.

If you look at figure 1 you will see that the equipment consists of—

One cylinder containing oxygen.
One cylinder containing acetylene.
Oxygen and acetylene pressure regulators.
A welding torch with necessary tips and mixing head.

Lengths of green or black hose for oxygen.
Lengths of red or maroon hose for acetylene.
Miscellaneous equipment such as goggles, lighter, wrench, and fire extinguisher.

If your shop has stationary equipment, it will look pretty much like that in figure 2. Here, the

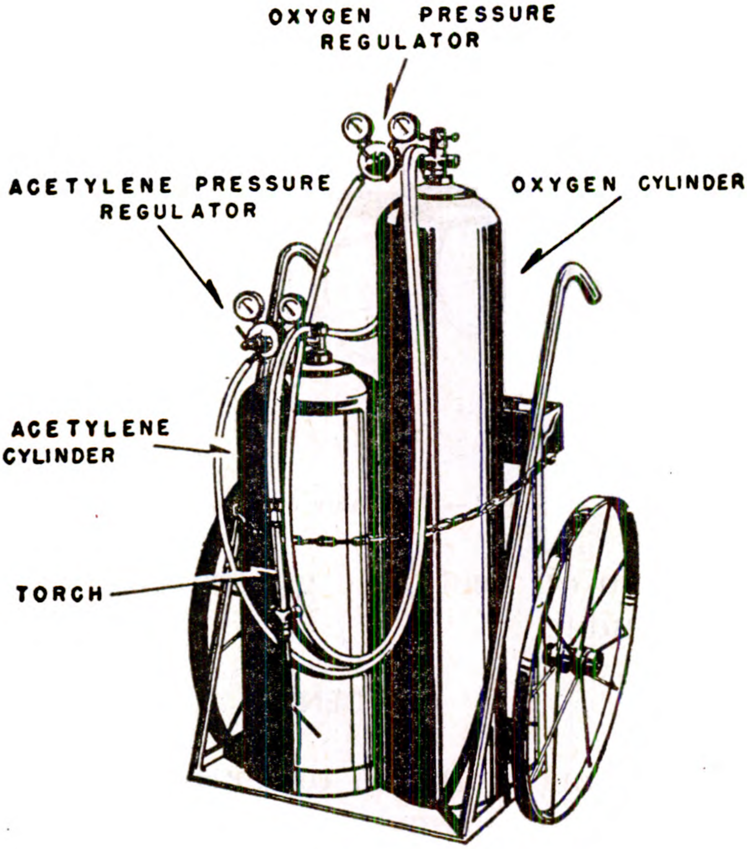


Figure 1.—Portable equipment.

acetylene and oxygen are piped to a number of welding stations. As you can see, each welder has space to work and a welding torch. He doesn't have to monkey around with the oxygen and acetylene cylinders themselves, however, because they are lined up in another part of the room. Also, they are connected to a manifold, and each bank of cylinders has a master regulator, which regu-

lates the flow of the gases. The manifold is that long pipe in figure 2 directly above the cylinders, into which the short pipe from each cylinder feeds. In some cases the acetylene is piped

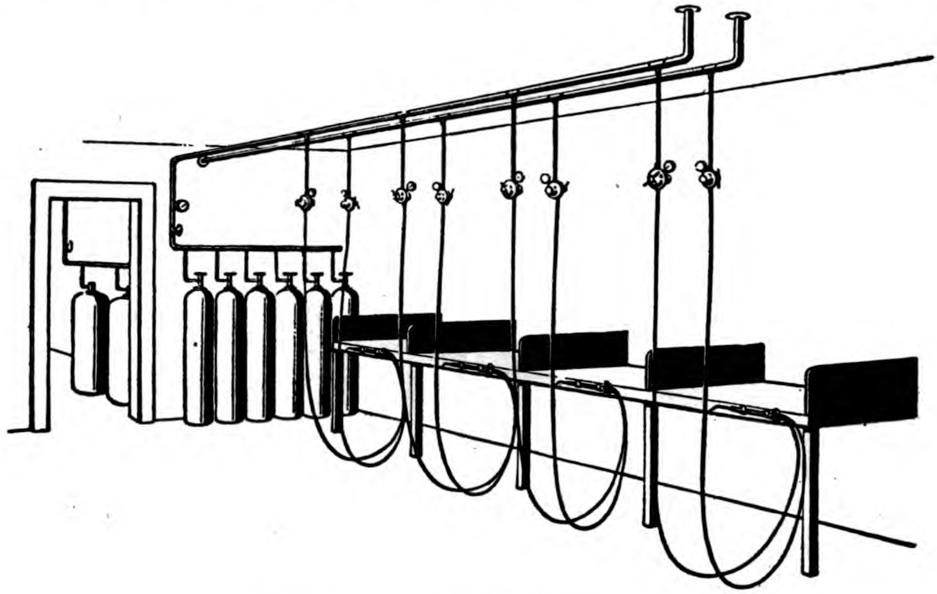


Figure 2.—Stationary equipment.

directly from an acetylene generator, rather than from a cylinder.

OXYGEN

Oxygen is necessary in order to get the acetylene to burn at a temperature high enough to melt metal.

In addition to being such a useful substance, oxygen is a very common one. But you can't see it, taste it, or smell it. Air contains about 21 parts of oxygen and 78 parts of nitrogen. The other 1 part is divided among rare gasses.

> WARNING.—If you want to keep on paying insurance premiums, remember that pure oxygen under pressure coming in contact with oil or grease will cause a violent explosion.

Figure 3 shows a typical oxygen cylinder. Such cylinders are made of steel. The oxygen is put into the cylinders at the factory under a pressure of about 1,800 pounds per square inch at 70° F.

Two standard sizes of oxygen cylinders are used—a small one having a capacity of 110 cubic feet of oxygen, and the standard size which holds 220 cubic feet.

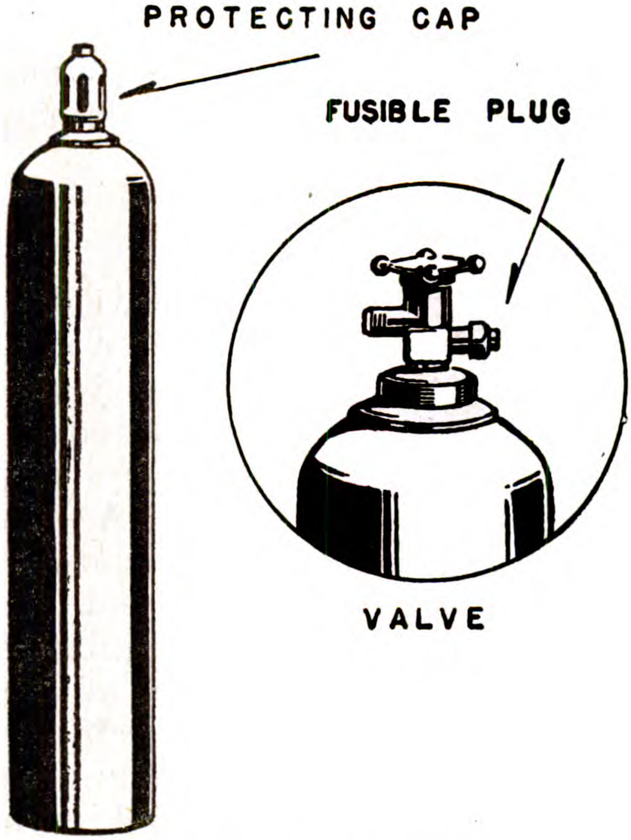


Figure 3.—Oxygen cylinder.

Oxygen cylinders are tested to withstand a pressure of approximately twice that normally put on them—a comforting thing to know.

In addition, a safety device is fitted to the top of each cylinder to relieve the oxygen in case the pressure in the cylinder gets out of hand for any reason- -for example, exposure to too much heat. Your feet swell when they get hot—so does oxy-

gen. When the temperature reaches about 240° F. the safety device breaks and releases oxygen, thus preventing any dangerous pressures in the cylinder. This device consists of a thin copper disk and a fusible plug arrangement.

The top of each oxygen cylinder is also equipped with a valve which regulates the flow of oxygen from the cylinder. This valve is covered with a protector cap, and, to prevent damage to the valve, you should make sure it is in place when the cylinder is not in use. For quite obvious reasons, it is definitely NOT GOOD to have damaged valves on your equipment.

FUEL FOR THE FIRE

Fuel for the high-temperature welding flame is supplied by the ACETYLENE. It is a colorless gas, but it has a peculiar odor which you can easily detect even when it is highly diluted with air.

Mixed with air or oxygen, acetylene forms an EXTREMELY EXPLOSIVE MIXTURE. A spark introduced into such a mixture will cause almost instantaneous combustion throughout the whole volume. The range of explosive mixtures is very wide—from 3 percent acetylene, and 97 percent air, to 82 percent acetylene, and 18 percent air. Thus, a small amount of acetylene escaping into a small room where you were smoking a cigarette might easily result in an explosion. And you'd NEVER KNOW what hit you.

To make matters worse, acetylene is self-explosive, even when pure, if it is kept under too great a pressure (20 psi). Therefore, as a safety measure, free acetylene should not be stored at pressures greater than 15 psi.

How can such a dangerous gas be shipped around the country without causing loss of life and property?

The answer is a variation of the old cotton-wool technique for wrapping fragile things. Instead of cotton-wool, the manufacturers place within the acetylene cylinder a porous substance such as soft asbestos packing or a residue called corn pith; and then saturate this substance with ACETONE. (Acetone is made by using a special process to distill—of all things—fermented corn.)

Acetone has the property of being able to absorb many times its own volume of acetylene. Actually, this absorption follows a definite rule: Acetone will absorb 25 times its own volume of acetylene when the pressure on the acetylene is 14.7 psi (1 atmosphere). When the pressure is increased an additional 14.7 psi, the absorption capacity of the acetone then becomes 50 times its own volume. This same ratio continues until a pressure of 16 to 17 atmospheres (about 250 psi) is reached. Beyond that point no more absorption will take place.

In this way acetylene can be handled safely at normal temperatures even when the cylinders are charged to pressures of 250 pounds per square inch. It is always a good idea, however, to treat acetylene with the same respect you would a rattlesnake.

Acetylene cylinders are usually built to hold either 100 or 275 to 300 cubic feet of the gas. The shell is of seamless steel, like the one in figure 4, and is equipped with a fusible-plug safety device to provide an escape for the gas if the cylinder becomes overheated. Since such escaping gas will very likely catch fire on contact with the air, the holes in the plug are small enough to prevent the flame from burning back into the cylinder in case the flowing gas is ignited.

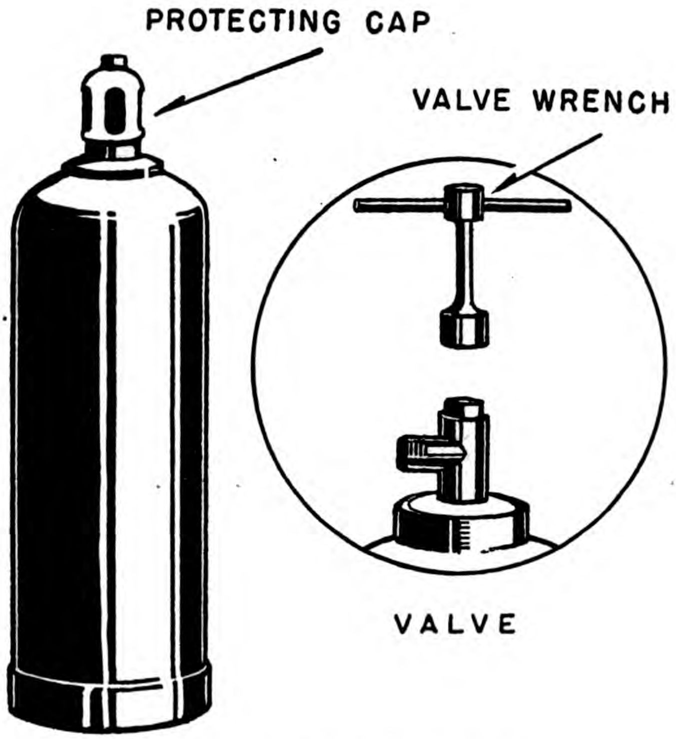


Figure 4.—Acetylene cylinder.

REGULATORS

Control is accomplished by means of regulators. The purpose of oxygen and acetylene regulators is to reduce the pressure and regulate the amount of gas flowing from the cylinder so that the gases reach your welding torch at the right pressures and in the correct amounts.

Regulators on cylinders are equipped with two pressure gages. A high-pressure gage tells you the pressure of the gas in the cylinder, and a low-pressure gage tells you the pressure of the gases flowing to the torch.

The high-pressure gage on the OXYGEN REGULATOR is graduated in pounds per square inch from 0 to 3,000 and the working-pressure gage (the one which tells you pressure of the gas as it flows to your torch) is usually graduated in pounds per square inch from 0 to 100.

Acetylene regulators are not made to withstand such high pressures as oxygen regulators, but otherwise the two are practically the same in design. On an acetylene regulator the high-pressure gage is capable of registering up to 500 pounds per square inch and the working gage may register as high as 50 pounds per square inch.

An oxygen regulator can be either a TWO-STAGE or a SINGLE-STAGE type. The two-stage type is preferable when you are using a portable welding outfit. The single-stage type may be used at the individual welding stations where the stationary type of equipment is installed.

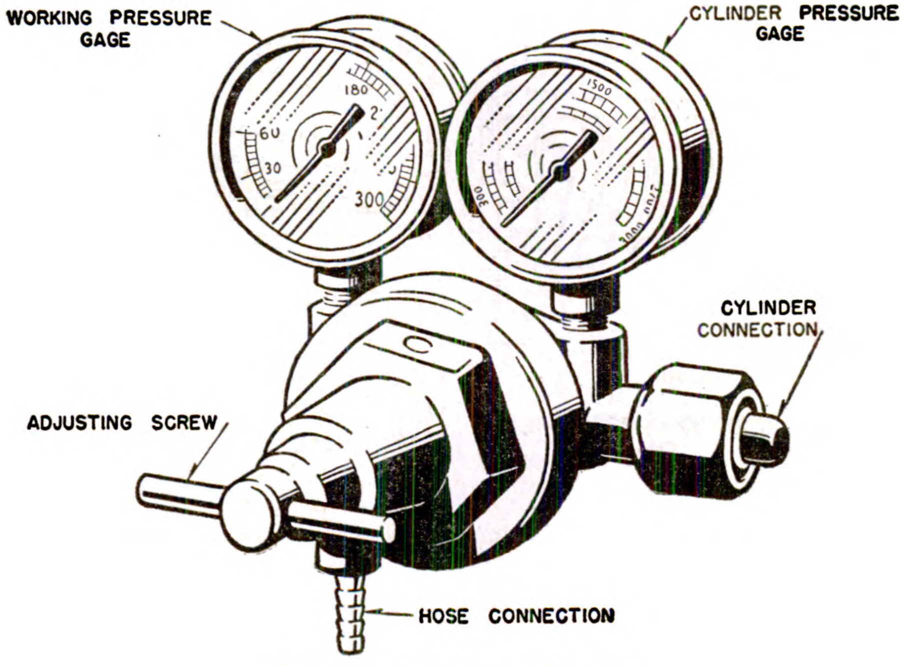


Figure 5.—Oxygen regulator.

The two-stage oxygen regulator has a double action. When you open the cylinder valve, the regulator automatically reduces the initial cylinder pressure to about 200 pounds per square inch. Then you turn the pressure-adjusting screw to the right (clockwise) until the required pressure is shown on the working-pressure gage.

Figure 5 shows a two-stage oxygen regulator. When you know how one of these regulators works, you will know WHY it is important to have the regulator CLOSED OFF BEFORE you open the cylinder valve. To CLOSE OFF THE REGULATOR, TURN THE PRESSURE ADJUSTING SCREW TO THE LEFT AS FAR AS IT WILL GO or until it feels loose. The pressure adjusting screw is thus RELEASED and in the position you see in figure 6.

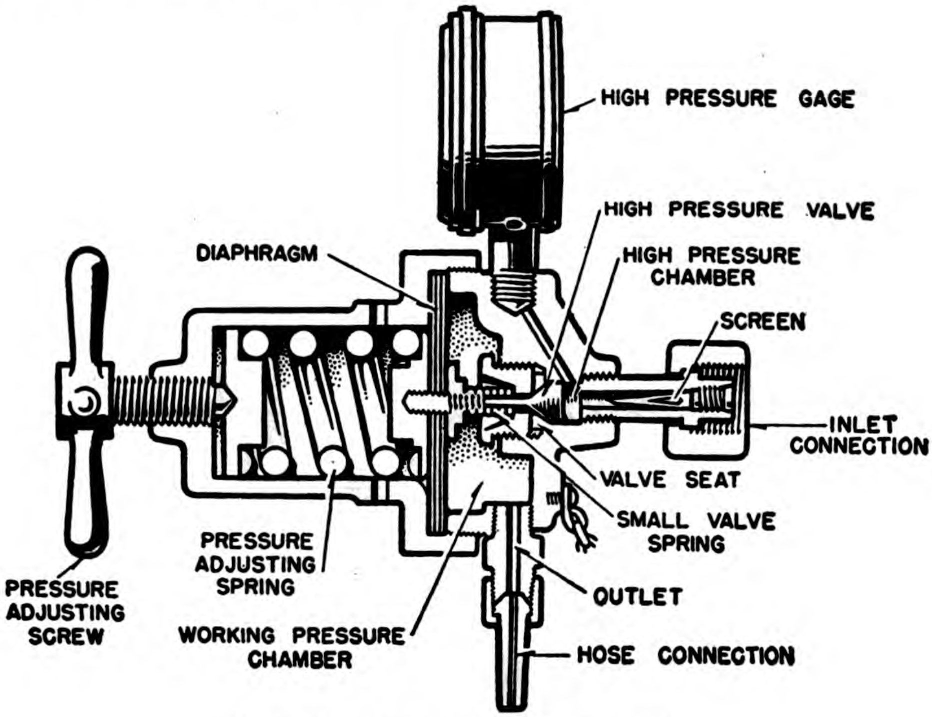


Figure 6.—Sectional view of regulator.

There is a very good reason why the pressure adjusting screw must be released before you open the cylinder valve. The oxygen gas is under high pressure—about 1,800 pounds—in the cylinder. While your two-stage pressure regulator has two gages, only one of them is built to handle the gas at high pressures. The working pressure gage is not built to withstand high pressures and will very likely be wrecked if gas is allowed to rush into it directly from the cylinder. And

that is exactly what happens if you open the cylinder valve without having first closed off the regulator.

If you open the cylinder valve AFTER the pressure adjusting screw has been released, all will be well. Gas will flow from the cylinder into the regulator through the inlet connection, into the high-pressure chamber, and up into the high-pressure gage, which is tough and able to handle the heavy pressure. During this journey, the gas forces the diaphragm of the high-pressure valve outward and closes the high pressure valve tightly.

On the other hand, IF YOU FORGET to close off the regulator before you open the cylinder valve, here is what will happen.

> The gas rushes into the high-pressure chamber and around the high-pressure valve, hell bent for election. But because the pressure adjusting screw is not released, there is an inward pressure on the diaphragm and connecting arm. This pressure keeps the high-pressure valve open, permits the gas to rush into the working-pressure chamber, and knocks the working pressure gage into a spin.
>
> So, DON'T FORGET.

THE TORCH

All of the equipment described so far has just ONE purpose—to get oxygen and acetylene to the WELDING TORCH. The torch usually is made up of a brass handle, oxygen and acetylene tubes within the handle, a torch head, a mixing head, and an assortment of tips of different sizes.

In figure 7, you can see that a needle valve for the oxygen and one for the acetylene are placed

like watch dogs at the points where the oxygen and acetylene tubes enter the torch head. You use these valves to regulate the volumes of acetylene and oxygen that enter the mixing head.

The torch head is usually located at the front end of the handle. The mixing head is carefully seated in the torch head and extends beyond the torch head. In the mixing head the two gases are properly mixed for the best burning condition.

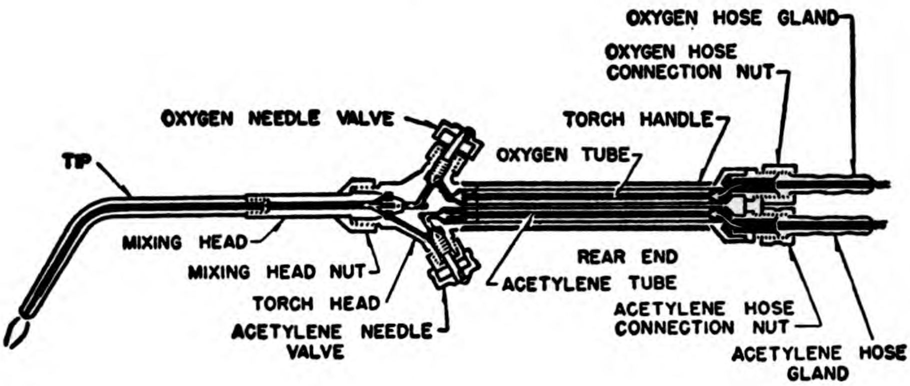


Figure 7.—A welding torch.

The mixture flows from the mixing head into the tip of the torch and emerges at the end of the tip where it catches fire and burns.

Welding tips are furnished in a number of styles. Some have a one piece, hard-copper tip. Others have a two-piece arrangement which includes an extension tube to connect the tip and the mixing head. In the two-piece tips the removable end is made either of hard copper or a copper alloy such as brass or bronze. Both types are numbered by size, each manufacturer having his own arrangement of classification. Some are labeled 0, 1, 2, 3, 4, and so forth, whereas others are marked 20, 21, 22, 23, etc.

HOSE

Hose, made especially for the purpose, is used to connect the welding torches to the oxygen and acetylene cylinders. The hose is nonporous, durable, strong, and as lightweight as possible. You can always tell by the color which hose is for oxygen and which is for acetylene. Red or maroon is used for acetylene, green or black for oxygen. In addition, the name of the gas is usually printed on the hose. They are made in lengths ranging from 12½ to 25 feet. The particular length used depends on how close to your

Figure 8.—Hose connections.

work your welding apparatus can be placed. Experienced welders like to use the shorter lengths if they can, because every additional foot of hose requires additional pressure to push the gas through. Long hose also kinks easily. These kinks hinder the flow of gas and result in wavering pressures.

At each end, the hose is equipped with a connection by which it is attached to its regulator outlet and torch inlet.

Since the results obtained by attaching the oxygen hose to the acetylene-regulator outlet would be anything but satisfactory, the designers have fixed it so that you CANNOT get the connections mixed up. A nut with a right-hand thread is used on the oxygen-hose connections. A left-hand nut is used on the acetylene hose. The left-hand

acetylene nut is generally marked with a groove around its center, as in figure 8, whereas the right-hand nut for oxygen is plain.

THE RESPECTFUL ATTITUDE

Your respect for the dangers involved in handling acetylene should not stop with merely being careful to avoid conditions which might cause explosions. You must also be careful to shield your eyes against the intense light produced by the welding flame.

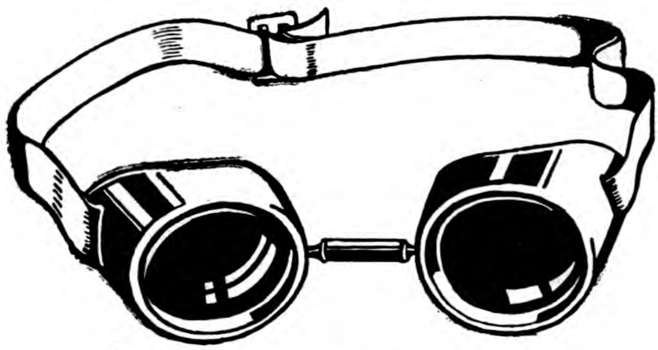


Figure 9.—Welding goggles.

This means HAVING the right kind of GOGGLES and WEARING THEM.

Welding goggles are fitted with colored lenses that keep out harmful heat and the ultra-violet and infrared rays produced in welding. You can pick your own lenses, but be sure thay are neither too dark for efficient work, nor so clear that they don't afford enough eye protection. These colored lenses have clear cover lenses to protect them from damage. Figure 9 shows a pair of welding goggles.

Even having the right type of lens is not enough if goggles don't fit. The cups of the goggles should hug your eye sockets closely to keep flying sparks and particles of hot metal from reaching your eyes.

It is just as poor an idea to borrow someone's goggles as it is to borrow someone's tooth brush. In addition to the sanitary reasons against such an exchange, you'll probably find that the goggles don't fit.

For heavy welding, gloves are frequently worn to protect the welders hands from sparks and hot metal. However, gloves are worn at the option of the welder.

Welding gloves are usually made of asbestos or chemically treated canvas.

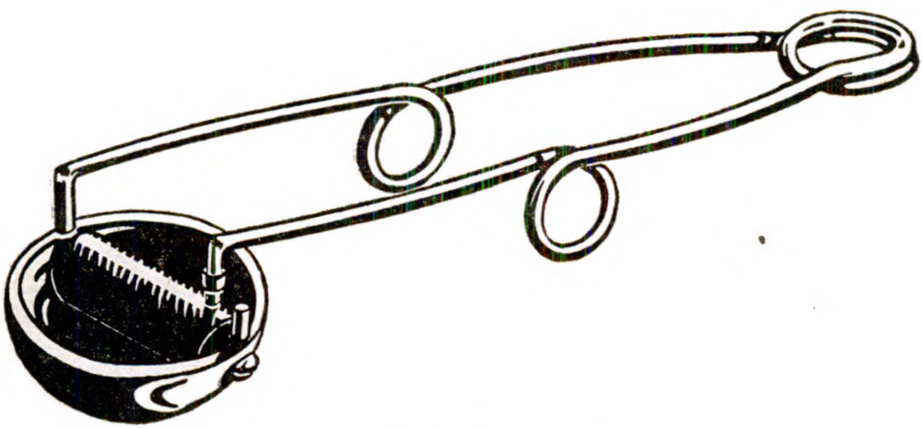


Figure 10.—Sparklighter.

Right at the start, you should get into the habit of using a SPARKLIGHTER to light the torch. NEVER use matches. Lighting by means of matches is dangerous because the puff of flame is likely to burn your hand. Figure 10 shows a typical sparklighter.

YOU SET UP THE APPARATUS

Occasionally, on your welding jobs you may find you have to set up the apparatus as well as to operate it. There is a definite order to follow in setting up your welding equipment for a safe, efficient job.

The first step is to FASTEN THE CYLINDERS. If they are not held firmly on a truck, tie them securely together—or better yet—fasten them to a workbench, wall, or post. This keeps them from being accidentally knocked or pulled over. DON'T remove the valve-protecting cap from a cylinder until just before you are ready to use it.

Figure 11.—"Cracking" a cylinder valve.

Next, you "CRACK" the cylinder valves. Stand at the side or behind the cylinder outlet and open the cylinder valve slightly for an instant. Then close it. In figure 11, you can see how to "crack" a cylinder valve in the approved manner.

This operation clears the valve of dust or dirt which may have settled in it during shipment or storage. Dirt in the cylinder valve is bad because it might mar the seat of the regulator inlet nipple

or, if carried into the regulator, might cause leakage.

The next thing to do is to CONNECT THE REGULATORS TO THE CYLINDERS.

Use a tight-fitting wrench to turn the union nut and be sure the nut is pulled up tight to prevent leakage of the gas, as in figure 12.

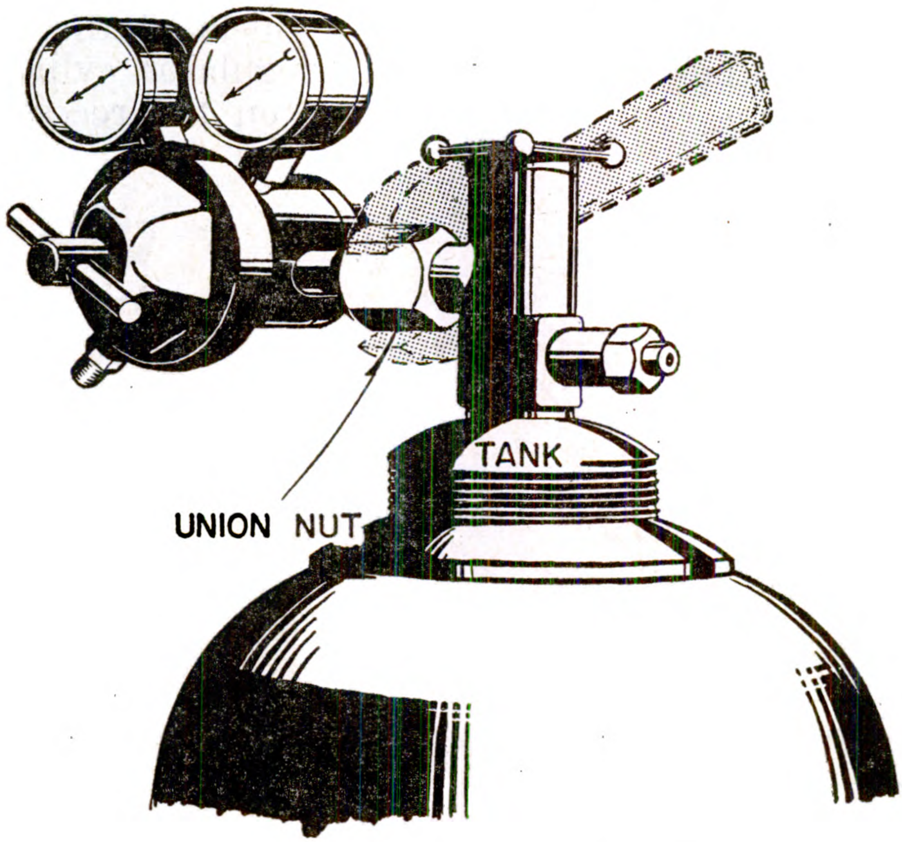


Figure 12.—Cylinder with regulator connected.

Leave the valve wrench in position on the cylinder ready for use in any emergency.

Sometimes you will find that the threads of the particular oxygen regulator and cylinder valve you have to connect don't exactly match. When this occurs, a fitting known as an adapter must be used. An adapter is a fitting which has threads at both ends. The threads at one end match the

cylinder valve while the threads at the other end match the regulator connection.

Use the same procedure in attaching the acetylene regulator to its cylinder.

RIGHT HAND THREADS

All oxygen regulator cylinder connections and hose connection outlets have right-hand threads. On the other hand, acetylene regulator cylinder connections constructed for use on the recessed-

Figure 13.—Attaching hose.

Figure 14.—Blowing out hose.

top type acetylene cylinders have left-hand threads. However, the regular Navy acetylene cylinder regulator connection has right-hand threads. In general, you may expect that all acetylene cylinder regulator connections, except the "recessed top type," have right-hand threads. The hose connection outlet on all acetylene regulators have left-hand threads.

In figure 13, you see the method of ATTACHING THE HOSES to their regulators—the oxygen hose is green and the acetylene hose is red.

If the hose is new, it must be blown out to remove loose talcum powder, as you can see in figure 14. To blow out a hose, open the cylinder valve and then turn the pressure-adjusting screw on the regulator in a clockwise direction until a pressure of 5 pounds per square inch shows on

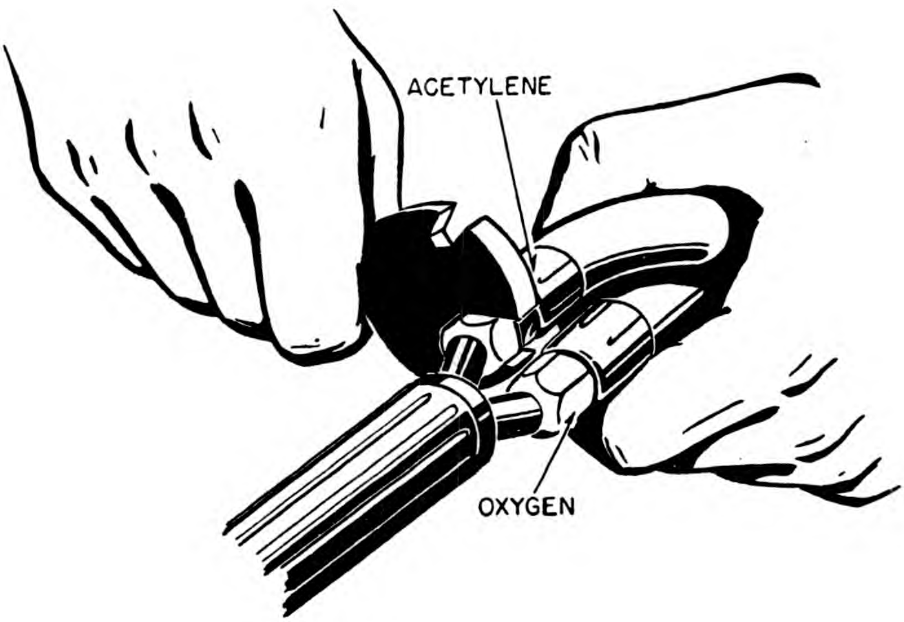


Figure 15.—Connecting hose to torch.

the low-pressure gage. When the hose is cleaned out, turn the adjusting screw back to the left until the pressure is released.

Then the other ends of both hoses must be connected to your welding torch as in figure 15. Always use a tight-fitting wrench to do this, so as not to ruin the edges of the nuts.

Now that your outfit is connected up, it is time to TEST FOR LEAKS. And you do NOT test leaks by holding a lighted match to the joints. The Navy uses soapy water and a brush, as in figure 16—and nothing else. NEVER use an open flame of any kind.

Before testing for leaks, close the oxygen and acetylene needle valves on the torch. Open the cylinder valves and then turn the regulator adjusting screws clockwise until a SLIGHT pressure registers on the working gages. Dip your brush in soap suds and spread over the connections. Any leaks will make the suds bubble up, and you

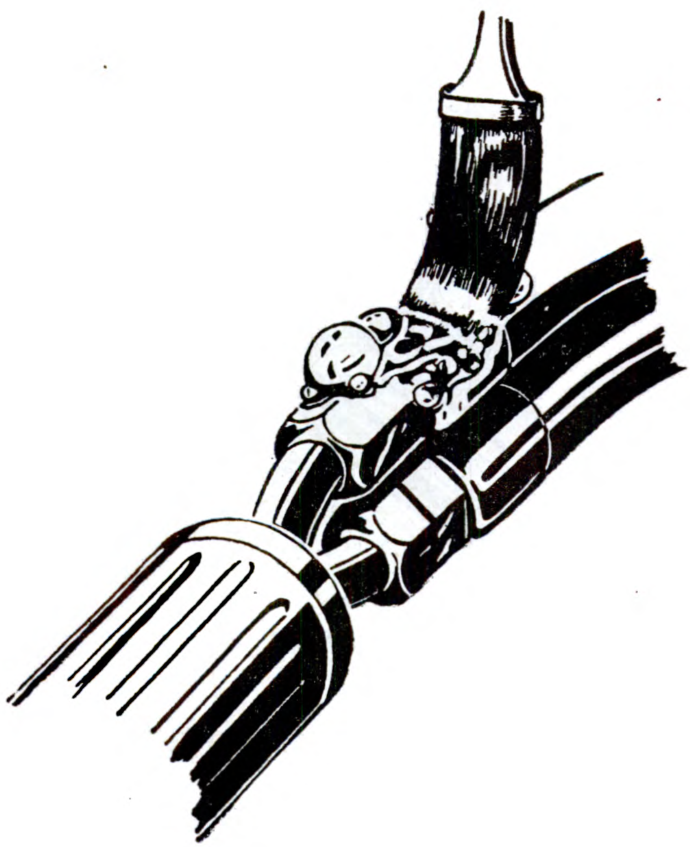


Figure 16.—Testing for leaks.

can spot it immediately. If you had a bicycle when you were a kid, you may remember spitting on the tire valves to find a slow leak. The soapsuds method is the same idea.

If you find a leak, close the cylinder valves and then hunt the source of the trouble. Usually a slight tightening of the connecting unit will stop

the leak. If it persists, it may be due to dirt in the connection, and cleaning out is in order. Or it may be due to marred threads or seats in the connection, in which case you may have to replace the connection.

TIPS ON TIPS

Now that your equipment is all set, you're ready to select the right size of welding tip. The size of the tip you use depends on the thickness of the metal to be welded. Thin metal calls for a tip having a small opening, while thick metal requires a tip with a larger opening.

TABLE I

Sizes of Tips for Various Metal Thicknesses

Thickness of Metal	Division of Orifice Tips in Inches	Oxygen Pressure Pounds per Square Inch	Acetylene Pressure Pounds Per Square Inch
24–22 (gage)	0.025	1	1
20–18	.035	1	1
16–14	.055	2	2
12–10	.065	3	3
⅛–3/16 inch	.075	4	4
¼ inch	.085	5	5

The importance of picking a small tip for light work and a larger tip for heavy work rests in the fact that the size of the tip determines the amount of heat applied to the metal. If you use

a small tip for heavy work, there will not be enough heat to fuse the metal at the right depth. If the tip is too large, the heat is too great and you'll find yourself burning holes in the metal. Table I gives the approximate tip sizes for various thicknesses of metals and also the recommended oxygen and acetylene pressures.

SETTING THE PRESSURE

ADJUSTING THE WORKING PRESSURE of the oxygen and acetylene as they flow into your torch is the next step after you have decided on your welding tip. First, open the cylinder valves. Then set the working pressures by adjusting the pressure screws on the regulators. And here is another hint if you would be a healthy welder.

> NEVER stand in front of a regulator when opening a cylinder valve. A defect in the regulator could cause the gas to blow through the glass and throw shattered glass into your face.

Make it a practice to STAND TO ONE SIDE of the regulator and turn the cylinder valve slowly, as you see in figure 17.

Remember, oxygen and acetylene are charged in the tank under high pressure so that, if you open the cylinder valves quickly, gas comes against the regulators suddenly and is apt to damage them.

When you are ready to open the cylinder valves, open the acetylene cylinder valve approximately one complete turn and open the oxygen valve all the way—BUT SLOWLY. Now set the working pressure for the oxygen and acetylene by turning the adjusting screw on the regulator clockwise until the correct pressure shows.

The amount of working pressure you use depends on the size of the welding tips you have chosen—and thus, indirectly, on the thickness of the metal.

Figure 17.—Correct position for opening cylinder valves.

LIGHTING THE TORCH

To light the torch, open the acetylene needle valve on the torch only enough to allow a little gas to escape. Then use your sparklighter to light the acetylene as it leaves the tip. REMEMBER! NO MATCHES. You should light the acetylene as quickly as possible to avoid wasting the gas. The flame will be large and yellowish red, and may be smoky on the outer edges.

Next open the oxygen needle valve slowly until all of the white feather-edged cone vanishes at

the tip of the white luminous inner cone. This white cone is surrounded by a second, bluish cone, which glows faintly and is from $\frac{1}{16}$ to $\frac{3}{4}$ inch long, depending on the size of the welding tip.

This combination flame is known as a NEUTRAL FLAME—so-called because there is an approximately one-to-one mixture of acetylene and oxygen. A neutral flame melts the metal without changing its properties and leaves the metal clean and clear. With most metals, you obtain the best welds by using a neutral flame. With certain types of metal, however, a flame with a slight excess of acetylene may be preferable. For instance, the nickel alloys, Inconel and Monel, both react better to a flame with an excess of acetylene. Brass, on the other hand, requires a flame with an excess of oxygen.

A neutral flame with exactly the right mixture of acetylene and oxygen allows the molten metal to flow smoothly, like syrup on a pancake. It also has very few sparks.

If the mixture is incorrect—with too much oxygen, for instance—the metal is burned, there is much foaming and sparking, and you obtain a porous, brittle weld. Too much acetylene increases the carbon content of metal, the molten metal boils and loses its clearness, and the weld is hard and brittle.

Any variation from a neutral one-to-one mixture will show up in the appearance of the flame. For instance, if you have more acetylene than oxygen feeding into the flame, it looks like the center drawing in figure 18. The flame is called a "carburized" or "reduced" flame. There are three flame zones instead of the two found in the neutral flame. The end of the brilliant white inner cone is no longer as well-defined and it is surrounded by an intermediate white cone which

has a feathery edge. There is still, however, the bluish outer cone.

If an excessive amount of oxygen is forced into the gas mixture issuing from the welding tip, the flame which results is called an "oxidizing" flame. This flame (see the third picture in figure 18) has only two cones like the neutral flame, but the

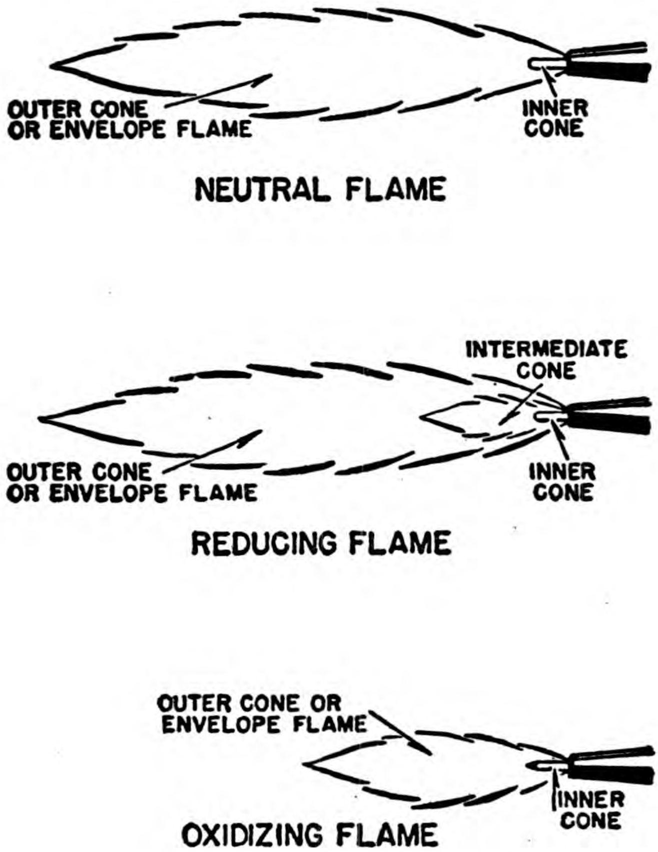


Figure 18.—Types of flames.

inner cone seems longer, is more pointed, and is almost purple instead of white. This flame burns the metal.

WELL-BEHAVED FLAME

When you have learned to adjust the flame so that the proportions of oxygen and acetylene are correct, you still may not have a good flame. A well-behaved welding flame is a SOFT flame. A

soft flame means that the gases flowing to the welding tip are coming through at comparatively low speed. Too great a pressure of both gases at the tip causes a HARSH flame which destroys the weld puddle and causes the metal to splatter around the edges of the puddle. Such a flame is noisy and you will find it extremely hard to get the metal to fuse properly.

Even when you have the correct gas mixture and the correct pressure, you can obtain a soft neutral flame only if the welding tip is ABSOLUTELY CLEAN. A good weld is hard to achieve unless the opening in the tip permits a free flow of gases. Any foreign matter in the tip restricts the source of heat necessary to melt the metal.

Just because you have the flame properly set, don't think that you can ignore it from there on. You must glance at it occasionally to be certain the mixture has not altered. Changes in the flame occur each time there is a slight fluctuation in the flow of gases from the regulators. You must keep an eye on your welding flame and make adjustments whenever they are needed.

A BACKFIRE (or torch popping) is caused by the preignition of the gases inside the end of the tip. The burned gases come out the end of the tip—usually accompanied by a loud report. An overheated tip is the direct cause of a backfire. Some of the reasons for a tip becoming overheated are: too little gas flowing from the tip; holding the tip too close to the work; or a dirty tip, either inside or outside. A single backfire is not too dangerous as it usually results only in blowing particles of molten metal from the weld. However, if backfires continue in rapid succession the torch should be turned off and the cause determined, as a flashback may result from the overheated condition of the tip.

A FLASHBACK is also caused by an overheated tip, which becomes hot enough to ignite the gas mixture inside the tip or mixing chamber. A flashback is different from a backfire in that the burning gases of a flashback travel back toward the source of supply. Flashbacks are dangerous and every effort should be made to avoid them.

The procedure for securing the welding equipment is as follows—

First, close the acetylene needle valve on the torch to shut off the flame.

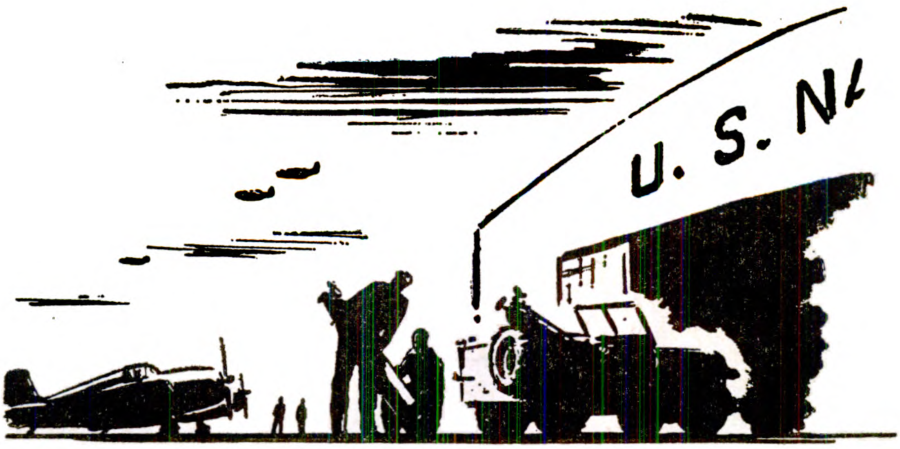
Then close the oxygen needle valve on the torch.

If you want to close down the entire welding unit, shut off BOTH the acetylene and oxygen CYLINDER VALVES.

Next, remove the pressure on the regulators' working pressure gages by opening the regulator and line.

Then open the torch acetylene valve. Close it when the working pressure gage drops to zero. Repeat with the torch oxygen valve. NEVER LEAVE BOTH TORCH VALVES OPEN AT THE SAME TIME when the torch is NOT in use. If the gases mix prematurely, a flashback may result and cause serious damage.

Finally, release the adjusting screws on the regulators—that is, turn them both to the LEFT.



CHAPTER 2

HOW TO WELD

START USING YOUR TOOLS

The first trick in learning to use the equipment described in Chapter 1 is to know how to hold the welding torch. There are two ways. In figure 19, you see how to grip the torch when you're welding light-gage (thin) metal. The hose drops over the OUTSIDE of your wrist and you hold the torch as if you were going to write with it.

For heavier work, a more comfortable way is to grasp the torch as you see in figure 20. Here you take hold of the torch as you would a hammer, with your fingers curled underneath. Whichever way you choose, let the torch balance easily in your hand so that it doesn't tire you.

FOREHAND AND BACKHAND

In September 1943, Lt. Joe Hunt, USN, won the National Tennis Singles because he had developed an excellent forehand and a nearly perfect backhand. If you can become as expert in forehand or backhand welding you'll be doing O. K. Figure 21 shows three types of torch motions you use.

Figure 19.—Pencil-like grip.

You may use either the straightforward motion (*A*), the semicircular motion (*B*), or the circular motion (*C*). Whichever motion is used, the point to keep in mind is to maintain as uniform a motion as possible, so as to leave smooth and evenly spaced ripples. When welding thin material, better results will be obtained by using a straightforward motion or a slight semicircular motion of the torch.

The FORWARD OR FOREHAND METHOD of welding is the best for thin-wall tubing and light-gage

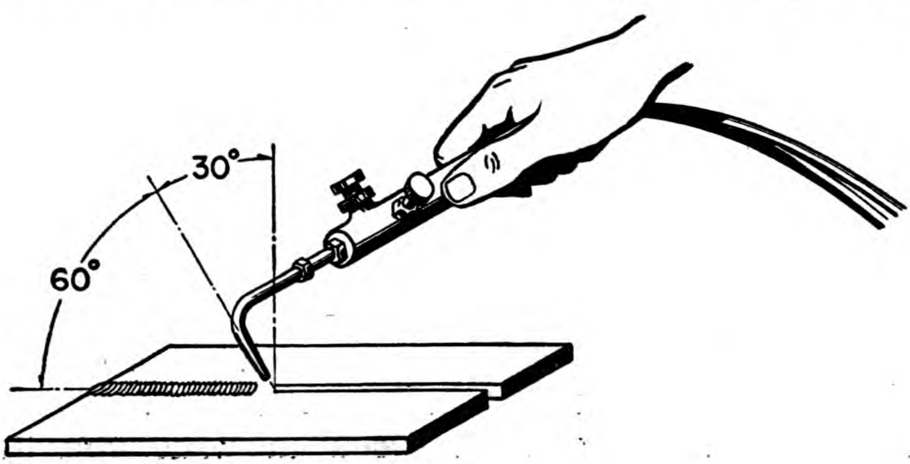


Figure 20.—Hammerlike grip.

metal. You hold the torch so that it is tipped sideways at an angle of 50° or 60° to the surface of your work, as in (*A*) of figure 22. As you can see, the correct position of the filler rod, if you are using one, is to add it to the little pool of molten metal which forms IN FRONT of the torch flame.

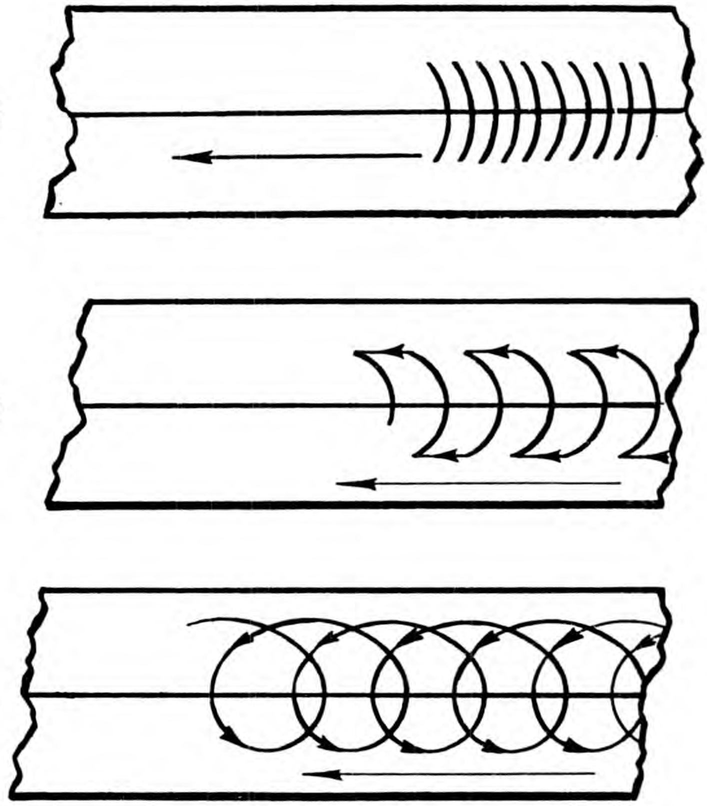


Figure 21.—Torch motions.

In the forehand method, you build up the finished weld (the shaded part of the bar in (*A*) behind the flame. The torch flame is pointed TOWARD the base metal (the white part of the bar in (*A*). "Base metal" means the metal on which you are making a weld.

BACKHAND WELDING is just the opposite. Here the torch flame is pointed toward the finished weld (the shaded part of the bar in (*B*) of fig. 22) at an angle of about 60° to the surface of

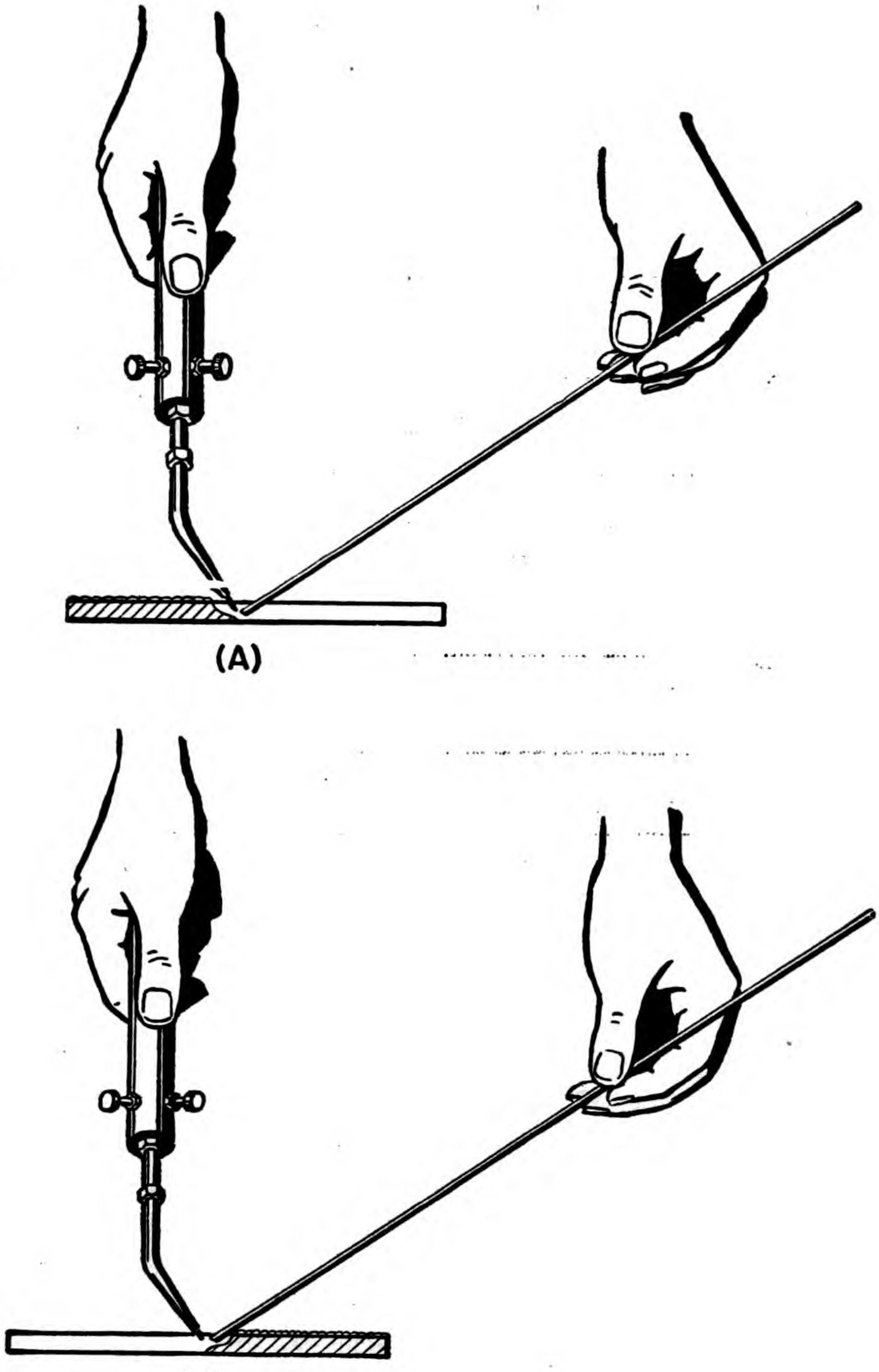


Figure 22.—(A) Forehand method; (B) Backhand method.

your work. The welding rod is added BETWEEN the flame and the finished weld.

In this backhand method, your semicircular torch motion should be directed so that the base of the arc you make falls TOWARD the finished weld. For instance, if you were welding a seam like the one in (*B*) you would use a right-to-left or counterclockwise motion.

Backhand welding is used to a good advantage on heavy metal because better penetration can be obtained with this method.

In either forehand or backhand welding the rod should be put into the molten puddle. This may be done by dragging the rod in the leading edge of the puddle or by dipping it in and out of the molten puddle as the weld progresses.

THE WELDING ROD—A GO-BETWEEN

A very important point to decide before you start welding is the kind and size of welding rod you will use. You must use a welding rod that is CHEMICALLY FRIENDLY to the "base metal"—that is, the metal you are working on—because the purpose of a filler rod is to add metal to your weld.

A chemically friendly filler rod means a rod having about the same chemical composition as the base metal. The reason for this requirement is that a welded joint should always possess as much strength as the base metal itself—an application of the old gag that A CHAIN IS ONLY AS STRONG AS ITS WEAKEST LINK. If the filler metal doesn't have the same chemical composition, your weld may be a weak link.

It is a mistake to use just any kind of wire for a filler rod because an inferior rod contains so many impurities that it is extremely difficult to

use. And besides, it makes a weld that is weak and brittle. A poor rod will spark a lot, flow irregularly, and leave the weld with a rough surface filled with pinholes. A good welding rod will flow smoothly and will readily unite with the base metal without any excessive sparking.

Filler rods come in a variety of sizes ranging from $1/16$ inch to $3/8$ inch in diameter. The size of rod you use depends on the thickness of the metal. A general rule is to pick a rod whose diameter is the same as the thickness of the base metal—for instance, if your metal is $1/16$ inch thick, your rod should be $1/16$ inch in diameter.

A great many different kinds of rods are available for welding metals. For instance, you use a mild steel rod for welding mild steel. (Mild steel is a soft, malleable steel that can be shaped by pressure.) You use a cast-iron rod for cast-iron, a nickel rod for nickel steel, and you use a bronze rod for bronze welding malleable cast-iron and other dissimilar metals.

In using the filler rod, you can either keep it straight or bend the end at an angle like the one in figure 23.

First bring the welding torch down until the white cone is about $1/8$ inch away from the surface of the base metal. Hold it there until the flame melts a small puddle of metal. Then insert the tip of the rod in this puddle and as the rod melts, gradually work the molten pool forward.

Don't move the torch ahead of the puddle but work along the edges of the seam slowly enough to give the heat a chance to break down the edges. If you get in a hurry and move the flame ahead too fast, the heat will not penetrate deep enough and the metal won't melt properly. On the other hand, don't be TOO slow about moving the flame

along. If the flame is kept in one place too long, it burns a hole through the metal.

Keep dipping the filler rod in the pool as the torch is advanced. But don't hold the rod too high because then the molten metal from the end of the rod will fall drop by drop into the pool. This "raindrop" technique gives you a finished weld that is full of pinholes. But that's all you'll

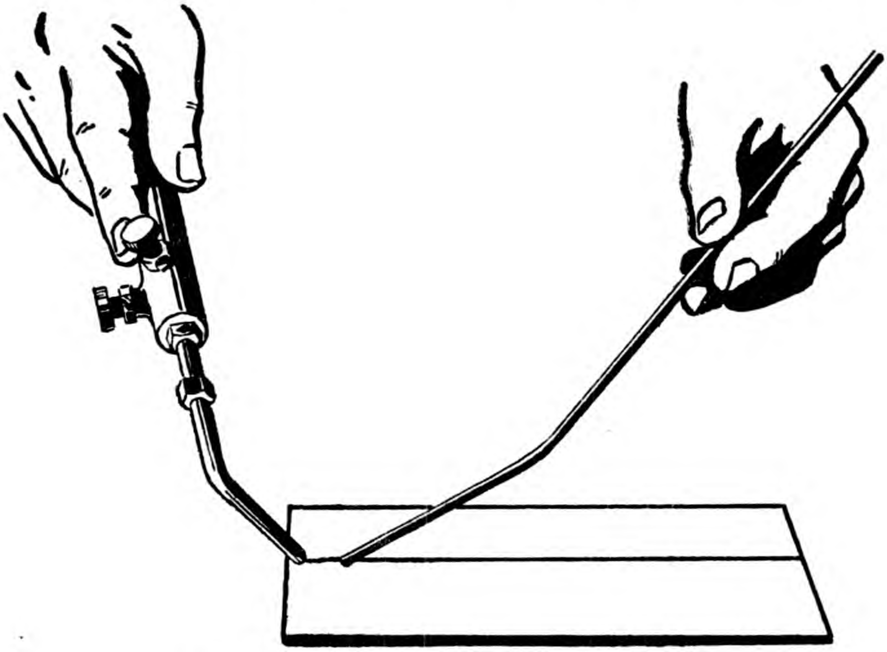


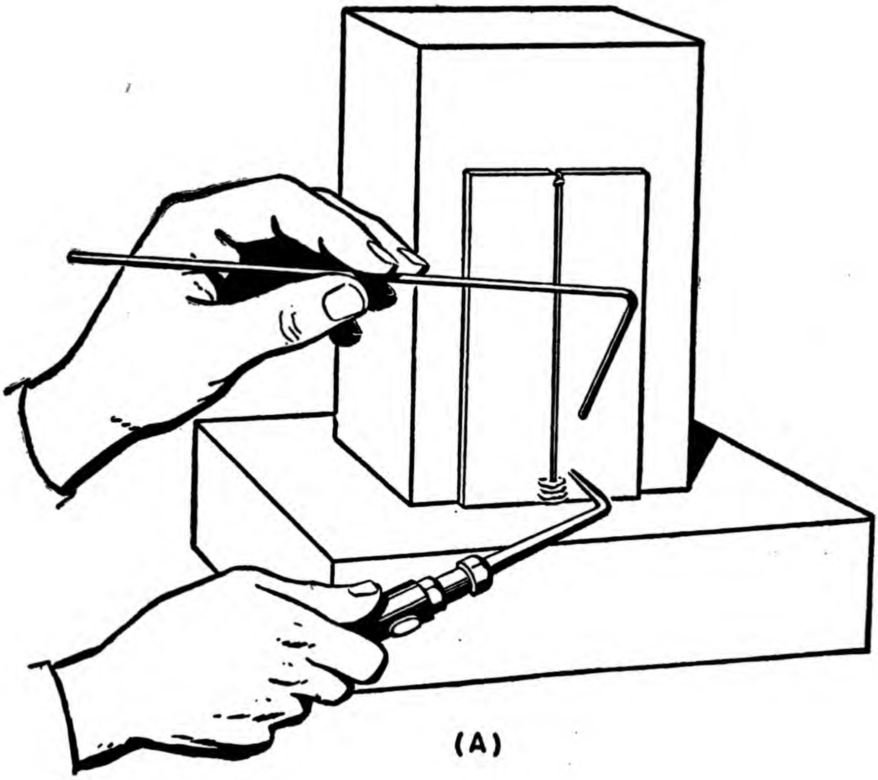
Figure 23.—Position for holding filler rod.

get. Nobody will give you a 4.0 mark for a job like that.

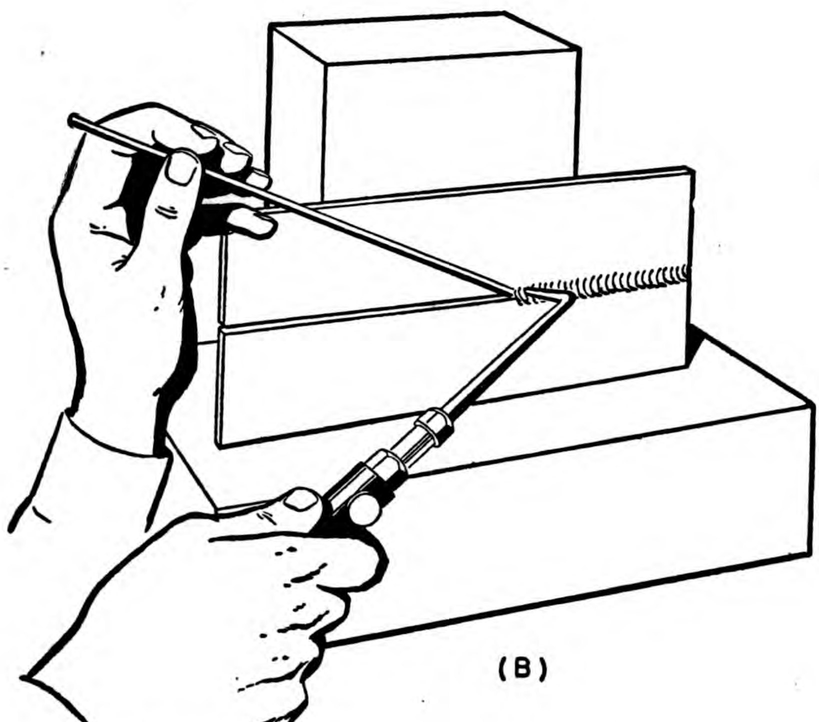
You usually don't need to put the rod directly under the flame. The heat of the molten puddle will melt it. Keep the flame concentrated on the base metal.

WELDING POSITION

You will find that there are four general positions in which the parts to be welded may be arranged. It will be your job to know how to make a good weld in any one of these positions.



(A)



(B)

Figure 24.—(*A*) Position for vertical welding; (*B*) position for horizontal welding.

First, there is the FLAT POSITION. The parts are laid flat on the table, as in figure 23, or tipped at an angle of less than 45°. The seam runs horizontally. You can use either the forehand or backhand method, depending upon how thick the metal is.

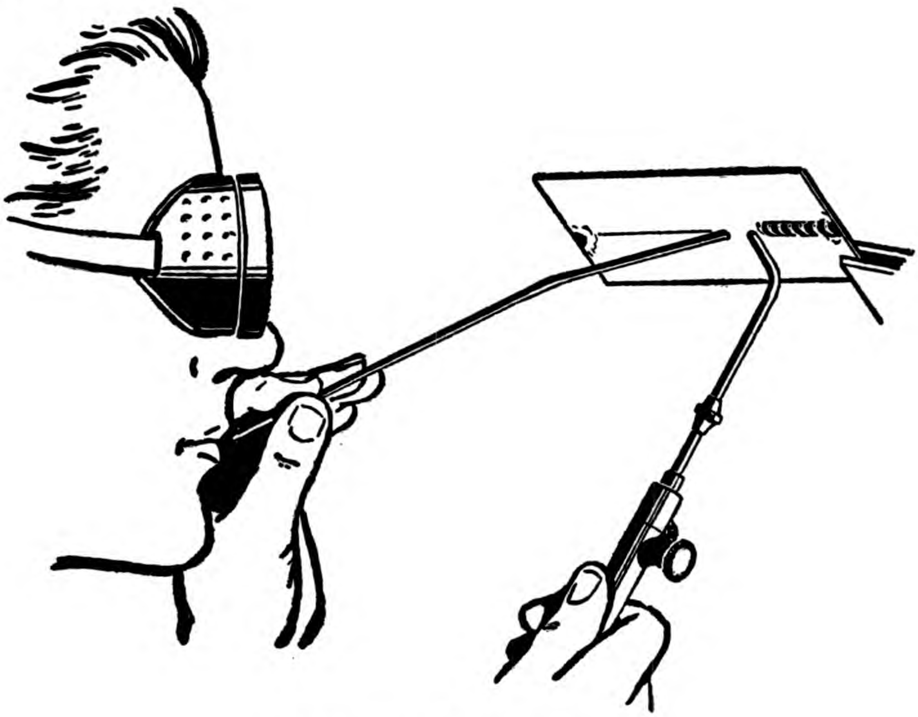


Figure 25.—Overhead weld.

The VERTICAL POSITION means that the parts to be welded are at a position of from 45 degrees to 90 degrees to the horizontal. In this position you should make the weld from the bottom up. [See figure 24 (*A*).] The torch flame is pointed upward at an angle of 45 degrees to 60 degrees to the seam.

When welding in a HORIZONTAL POSITION the plate to be welded is placed in a vertical position with the joint to be welded running horizontally. [See figure 24 (*B*).] You can weld a seam in this position by either the forehand or backhand method. In either case, the flame should point slightly upward. This is to keep the molten metal

from running to the lower side of the seam. If you are using a filler rod, you should add it to the weld at the upper edge of the melting zone, as it absorbs some of the heat and provides enough chill to help hold the melting metal in place.

When a weld is made on the under side of the work, it is called an OVERHEAD WELD. (See figure 25.) Here again you may use either forehand or backhand technique. While the flame must be pointed upward, it is held at approximately the same angle as for welding in a flat position.

Control the volume of your flame so that it doesn't exceed what is required to get a good union of the base metal with the filler rod. Obviously, you must avoid having a large pool of melting metal or the metal will run out of the joint.

PREPARE YOUR METAL

If you want to save yourself a lot of grief, you might as well start right now memorizing the first law of welding.

PREPARE CAREFULLY THE METAL PARTS YOU WISH TO JOIN BEFORE YOU MAKE ANY ATTEMPT TO WELD THEM.

Preparing the metal includes cleaning the surfaces; beveling the edges, if necessary (that is, shaping or grooving the edges so that they slant); arranging the parts in the right position for welding; and devising the correct support for the parts.

If you know all about welding equipment and how to use it, you still won't be the fair-haired boy around the shop unless you also know how to prepare the metal to insure a sound weld.

All scale, rust, oxides, and other impurities MUST BE REMOVED from the edges and surfaces of the metal around the joints because you don't want them in your weld.

The next step in preparation of the edges or ends of the parts to be welded is BEVELING them down with an emery wheel or file so they will fuse with a minimum of heat. Whether or not you bevel the edges depends on the thickness of the metal. For example, if you have two pieces of steel 1 inch thick to weld together, you would find it impossible to get at the center of the material. Therefore you could weld only the outer edges of the crack or seam. But if you bevel or "V out" the joint, you are able to make a weld that goes all the way through.

The reason for welding with a MINIMUM OF HEAT is that excessive heat at the point of the weld CAN burn the metal. It will also radiate out from the weld into the base metal, causing unnecessary expansion and contraction of the metal. Always avoid using too much heat and you will prolong the life of the metal.

TYPES OF JOINTS

In general, there are FIVE different types of joints—butt joints, tee joints, lap joints, corner joints, and edge joints.

Figure 26 shows four ways of preparing a BUTT JOINT—that is, a joint in which the parts are joined end to end without overlapping. You may use the FLANGE BUTT JOINT (*A*) for very thin sheet metal up to 0.0625 inch in thickness.

Turn up each edge at an angle of 80° or 90° to make a short flange with a height of from one to three times the metal's thickness. Then melt down these flanges so that they fuse together to make the weld. A filler rod is not used for this type of joint since the flanges furnish enough metal to fill the seam.

The PLAIN BUTT JOINT (*B*) can be used for metals from 0.0625 inch to 1/8 inch in thickness. For the plain butt joint you must use a filler rod in order to get a strong enough weld.

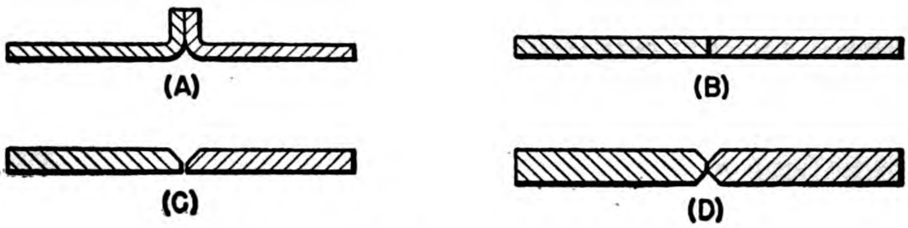


Figure 26.—Types of butt joints.

For metals thicker than 1/8 inch you have to BEVEL THE EDGES as in (*C*) or (*D*) so that the heat from your torch can penetrate completely through the base metal. You use a filler rod for these welds also.

The PLAIN TEE JOINT (*A*) of figure 27 requires no preparation other than cleaning the end of the vertical part, and the surface of the horizontal part. The weld is made at the base of the vertical part, from both sides, so that heat penetrates into the intersection, or root, and is called a "fillet"

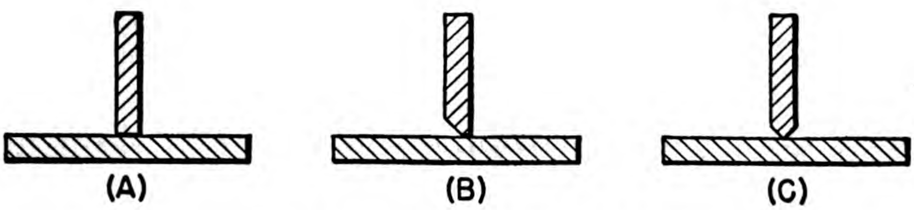


Figure 27.—Types of tee joints.

weld. This joint is suitable for most of the metal thicknesses you encounter in aircraft work.

If the parts to be welded are from 1/8 to 1/2 inch in thickness, bevel the end of the vertical part on one side as in (*B*).

If the parts are thicker than ½ inch you should bevel the end of the vertical part on both sides as in (*C*). Use a filler rod when you weld any of the tee joints shown in figure 27.

LAP JOINTS like those in figure 28 are used a lot in making equipment from sheet and plate metal (flat, wrought metals). The lap joint, however, is not as efficient as the butt joint for distributing load stresses.

The SINGLE WELDED LAP JOINT (*A*) is used for sheet, plate and structural shapes where the load is not severe. The DOUBLE WELDED LAP JOINT (*B*) is used for sheet and plate parts where you want the welded sections to have greater strength.

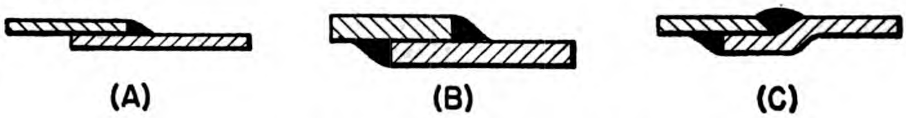


Figure 28.—Types of lap joints.

The third picture (*C*) shows a weld which takes a dog-leg jog and is called, obviously enough, the "JOGGLED" or OFFSET LAP JOINT. An offset lap joint is used for sheet and plate parts where you want one side of both plates in the same plane, or level, as are the top edges of the two plates in *C*. All of these lap joints require the use of a filler rod.

EDGE WELDS like those in figure 29 come in handy for fittings made up of two or more pieces of sheet metal where the edges must be fastened together and where you aren't worried about the load stress.

If your sheet metal is thin, you can use the first type (*A*) but (*B*) is better for heavier sections. The edge weld (*A*) doesn't require a filler rod, since on the thin material you can melt down

sufficient metal to fill the seam and still have a thick enough weld.

However, (*B*) in figure 29 is another story. Here the parts are thicker. You have to bevel or groove the edges, and add filler metal from a welding rod to obtain a strong joint.

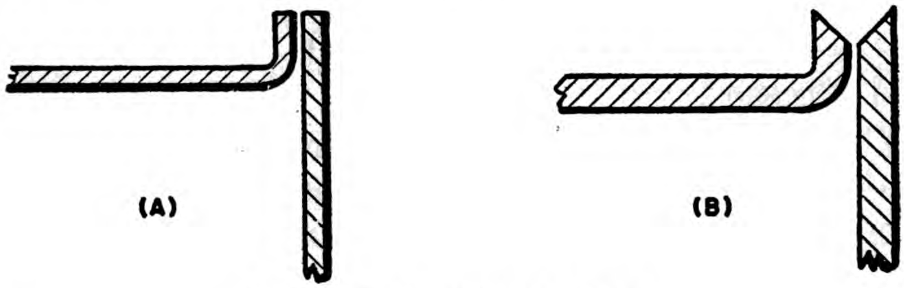


Figure 29.—Types of edge joints.

If you are called upon to weld a box, the joints shown in figure 30, known as CORNER JOINTS, are the ones you will use in constructing the box. Figure 30 shows the different kinds of corner

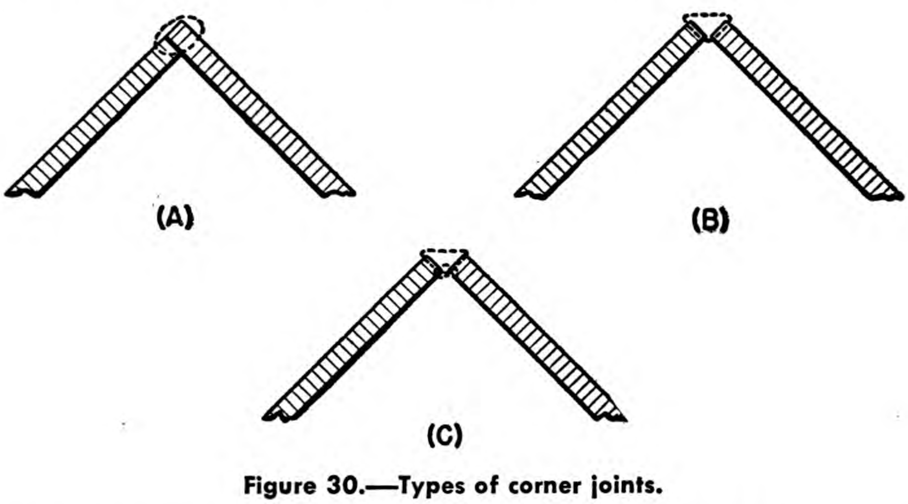


Figure 30.—Types of corner joints.

joints commonly used in making tanks, boxes, and other articles out of sheet and plate metals.

The CLOSED TYPE OF CORNER JOINT (*A*) is used on thin sheet metals where you don't have to worry much about the load the joint will have to carry. It is made by lapping one piece over the

other to make the corner. You add little or no filler rod to the closed corner joint because the edge of the overlapping sheet is melted down and fused to make the weld.

The OPEN JOINT (*B*) is used on heavier sheet metal. You fuse the two edges together and add enough filler rod to form a well-rounded bead of weld metal on the outside. If such an open joint must bear a fairly heavy load you must make a weld on the inside corner as well, to give it even greater strength, as in (*C*).

Any weld which joins two parts that are at right angles to each other is known as a fillet weld—thus edge joints, lap joints, and corner joints all require fillet welds.

PARTS OF A WELD

Now that you have learned about the types of joints you use, the next step is to USE them in welding. But first stop and look at a weld for a minute. The weld you make has certain parts, each of which has a name. And you might as well learn them now.

Figure 31 shows a plain butt weld in which two pieces of metal are joined end to end.

The REINFORCEMENT is the amount of weld metal added above the surface of the base metal (the metal in the parts you are joining). Figure 31 is a cross-section of a weld bead. PENETRATION is the distance the weld metal extends into the base metal. For good penetration the base metal at the joint must be melted THROUGHOUT its thickness. That is, a bead of weld metal should actually be visible on the under side of a butt joint as you see in figure 31. In the case of a fillet weld, the presence of scale on the under side is a good indication of penetration.

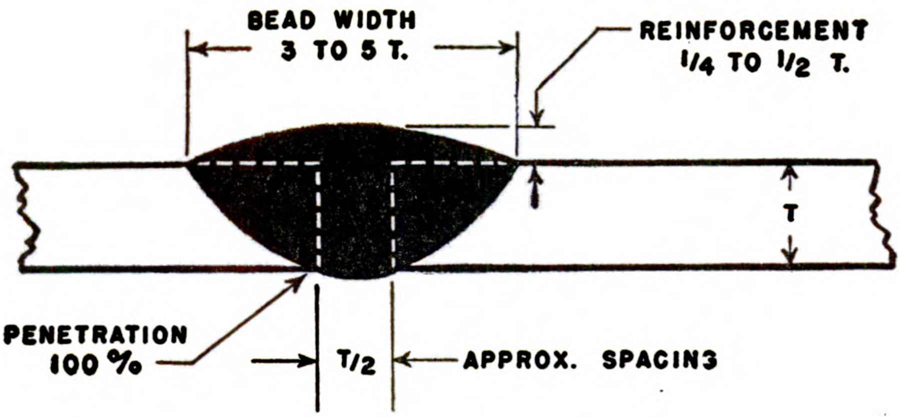


Figure 31.—Butt weld.

WELD PROPORTIONS

A VERY IMPORTANT part of your welding equipment is the information you retain about the proportions of welds in relation to the thickness of the base metal. Here are the three proportions to watch—

Width of bead.
Depth of penetration.
Height of reinforcement.

ALL of these vary according to the thickness of the base metal.

Take the width of bead, for instance. A good rule to follow for making lap welds for thin metal joints in aircraft is to make the bead 3 to 5 times as wide as the base metal is thick, as in figure 32. In attaching aircraft fittings by use of a lap weld, the width of the fillet bead should be 3 to 5 times the thickness of the thinner sheet.

PENETRATION

Penetration on a lap weld should be 100 percent of the top plate and from 25 to 50 percent of the lower plate.

A fillet weld for a TEE joint is a common aircraft weld. (See figure 33.) The penetration on this weld should range from 25 to 50 percent the thickness on both legs.

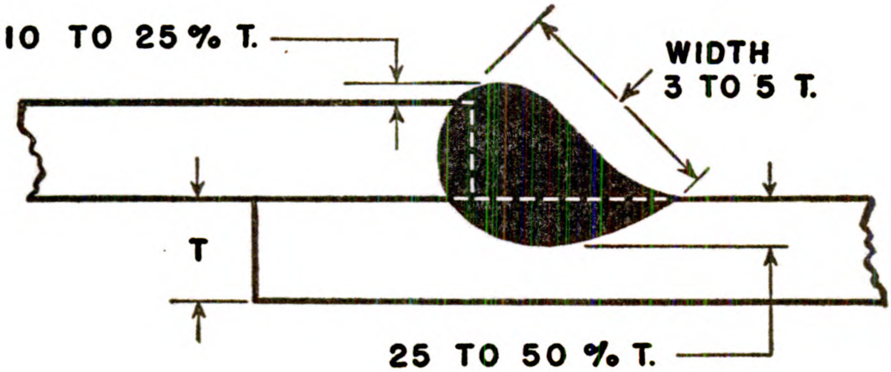


Figure 32.—Lap weld.

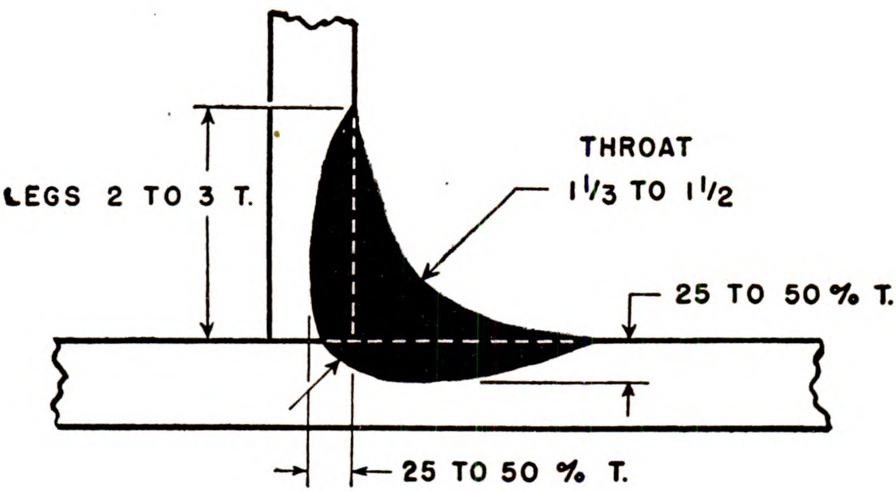


Figure 33.—Fillet weld.

EXPANSION AND CONTRACTION

Changes in temperature affect the length, breadth, and thickness of a piece of metal. The greater the change in temperature, the greater the effect on the metal. Whenever heat is applied, expansion forces are set free in a piece of metal

which make it grow larger. Then, upon cooling, the same metal will shrink or contract as it tries to return to its original shape.

But the only time YOU have to worry about these forces of expansion and contraction in metal, is when there is some restriction. For instance, in a trussed frame, there is a restriction of the free movement of the metal parts. When such restrictions are present and the metal is malleable, warping will occur. If the metal is brittle, it may crack. On the other hand, if the metal piece is "open"—that is, if there are no obstructions in the way of free expansion and contraction—you can pretty much ignore this aspect of metal.

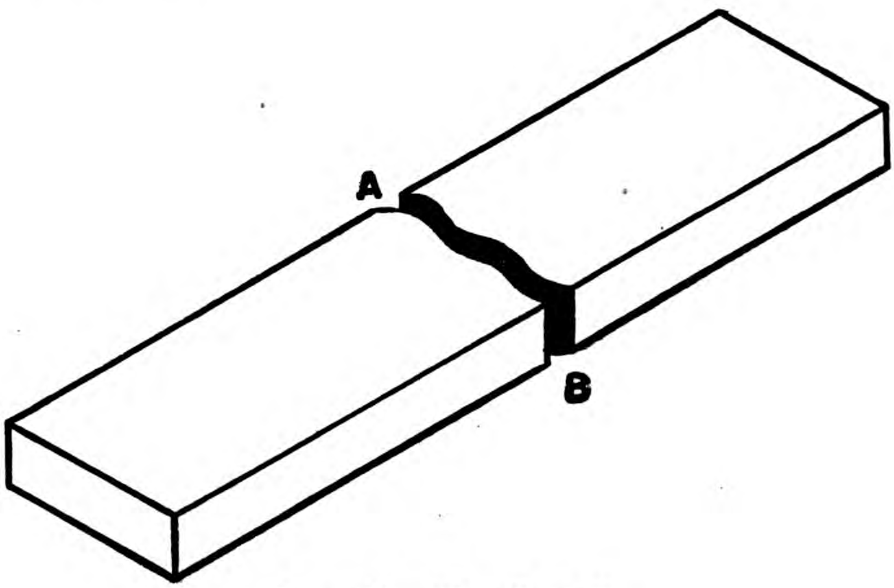


Figure 34.—"Open" metal.

Figure 34 is an example of "open" metal. Here is a bar without any obstructions present at the ends to hinder the metal from expanding and contracting as much as it wants to—assuming you were to heat up the bar by welding the break.

BUT suppose this bar is a center section as in figure 35. In this case, the ends of the bar are

fastened rigidly to a solid frame. If you weld the break and do not make provision for expansion and contraction, you're in for trouble.

In the first place, the crosswise and lengthwise sections of the frame are rigid and will not allow the ends of the centerpiece to expand. Thus

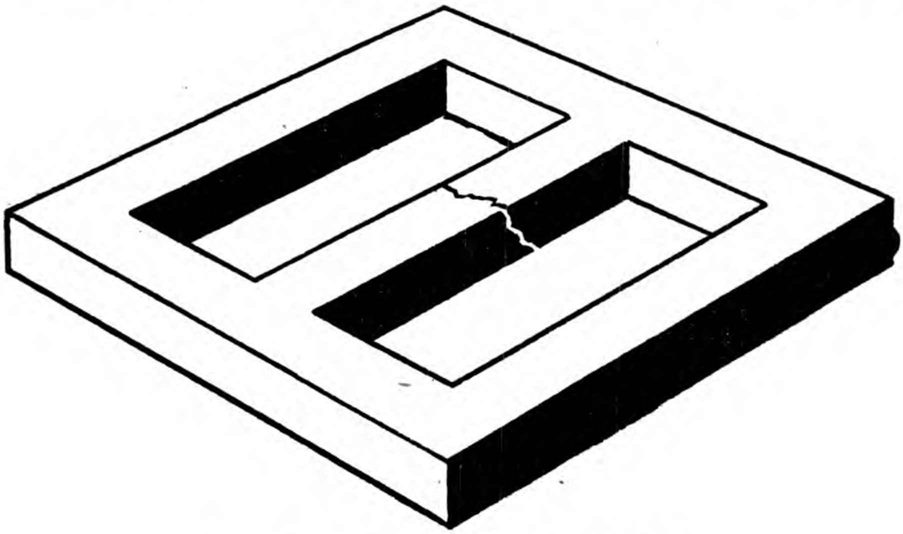


Figure 35.—Closed metal—a rigid joint.

there is only one place where this expansion can occur while the metal is being heated. That place is at the point of the weld itself. But what happens when this section begins to cool? The center bar contracts and becomes shorter. The rigid frame around it, however, is still the same size and since it is cold, refuses to give in to the inward pull of the ends of the contracting center bar. Then a break, or at best, warping occurs either at the line of the weld or somewhere else.

On the other hand, if you had heated the whole piece BEFORE attempting to weld the break, the ENTIRE PIECE would have expanded equally, pulling apart the two edges of the break from *A* to *B* in figure 35.

Then after you had made your weld, the entire piece including the weld metal, would have cooled

and approximately the same amount of shrinkage would have taken place throughout. RESULT—no warping, no cracking.

The principle of this illustration can also be applied to more complicated welding problems.

HOW TO CHECK EXPANSION AND CONTRACTION

There are a number of methods you will find useful in keeping under control the expansion and contraction of your metal. The distortion from such swelling and shrinking, by the way, is especially noticeable when you are welding long sections of thin sheet metal. The thinner the metal, the greater the distortion.

Some of the following procedures may help to control the effects of expansion and contraction caused by welding—

Tack the material.
Use clamps, jigs or chill bars.
In some cases, pre-heat the entire piece.
Rapid welding.

The nature of the welding job will determine whether you use one, or any combination of these controls.

Pre-heating is the type of control to be used for joint in figure 35. It means preheating the ENTIRE SECTION of the metal before you do any welding. Preheating the sections sets free all the stored-up forces and permits a more uniform contraction when the weld is finished.

Controlling the amount of heat put into the weld may be hard for you at first. An experienced welder, who can breeze through a weld and finish it very quickly, can joint two edges with the minimum amount of heat necessary to make them fuse properly. Another way to get by with

the least heat possible is to use a method called the "stagger weld." In stagger welding, you weld a little while at the beginning of the seam, then skip to the center, then skip to the end, as in figure 36. You then come back to where the first weld ended and repeat the process until you have completed the weld.

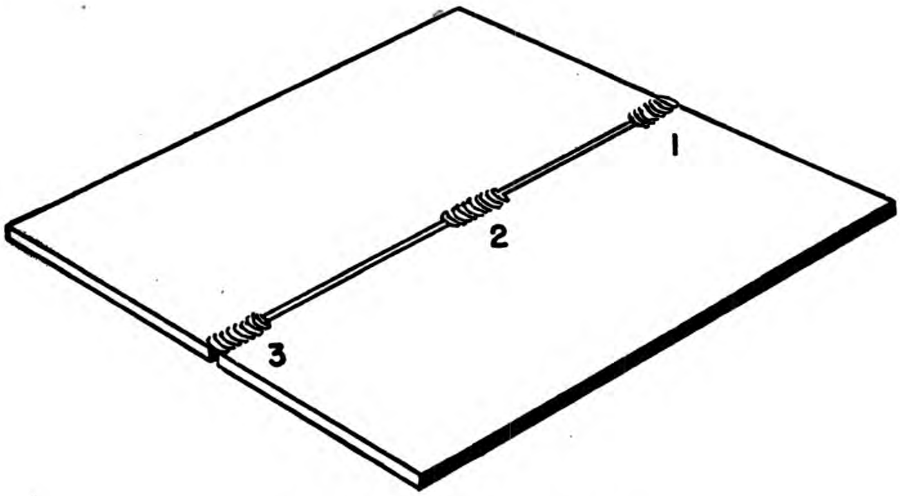


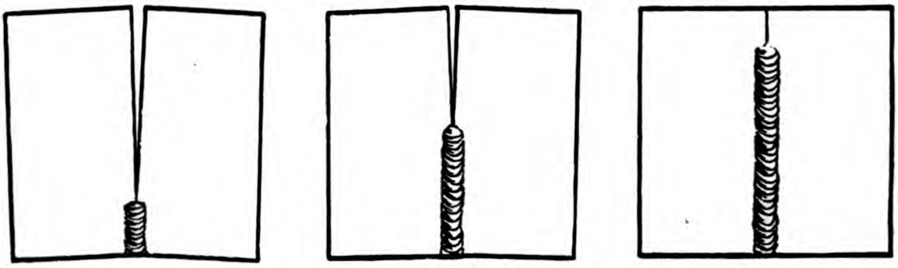
Figure 36.—Stagger welding.

This hop, skip, and jump technique—by preventing any one area of the piece from absorbing a lot of heat—checks buckling and cuts down the tendency toward cracking.

Since holding the metal in a fixed position hinders any excessive movements, you can use jigs to prevent bad distortion caused by expansion and contraction. A "jig" in welding is any contrivance that holds the metal sections rigidly in place while you weld a seam. Jigs SHOULD NOT, however, be fastened so tightly that they hinder normal expansion and contraction of the metal at the ENDS of the joints. If fastened too tightly, they cause internal stresses in the metal which weaken its ability to bear loads. These jigs may be nothing fancier than a few clamps to hold

down the metal, or they may be complicated affairs for production purposes.

You can also keep down distortion caused by the effect of heat on metal if you are careful to SPACE THE PIECES CORRECTLY. The experienced welder will tell you that it is smart to allow a TAPERING SPACE between the pieces—a distance equal to the thickness of the metal for every foot of seam length, as in figure 37. For instance, if



(A) (B) (C)

Figure 37.—Proper spacing.

you have to make a joint between two pieces of metal which are 1/4 inch thick and 1 foot long, the space between them should be 1/4 inch at the ends opposite the starting point. And, if these same pieces were TWO feet long, the space at the wider ends would be 1/2 inch.

WILL IT HOLD?

You ought to use a couple of simple tests to check your welds occasionally to see whether or not you're on the beam.

A BEND TEST is one method of testing your work. Let the metal cool slowly. Then pick it up with a pair of pliers. Then clamp the piece in a vise with the weld parallel to the top of the jaws and just a little above the top of the vise as in figure 38. Strike the top of the metal with a hammer, so that the metal is bent along the line of the weld. Always make the test so that

the weld is bent in on itself—that is, so that the bottom of the weld is put in tension and the top in compression.

A weld which breaks off very sharply and shows a dull, dirty fracture and the presence of blow-

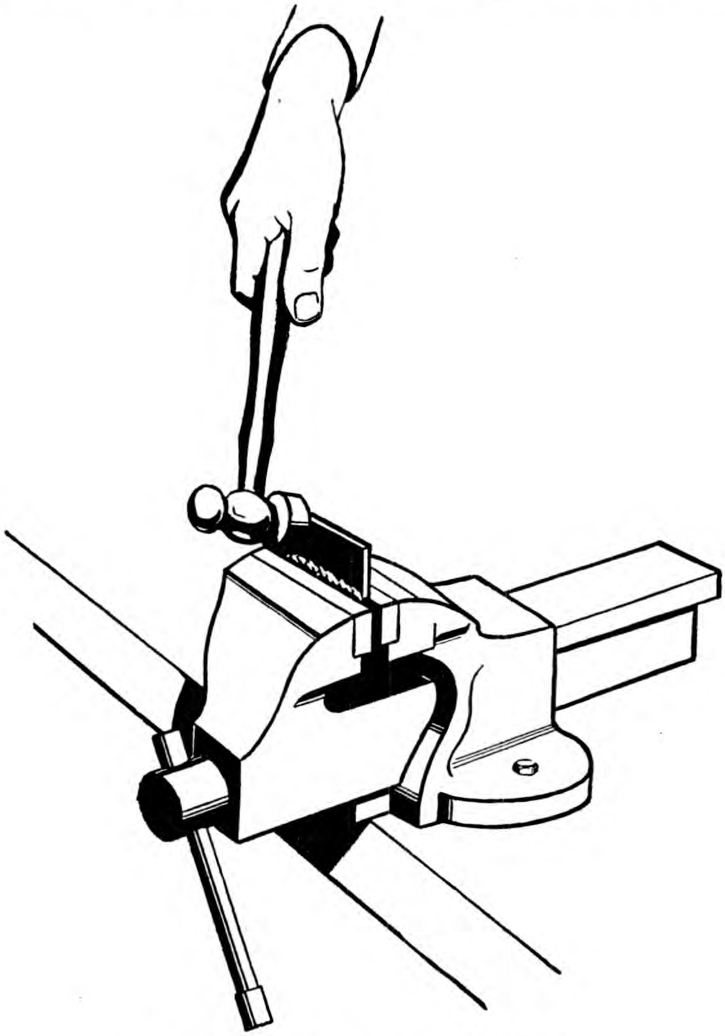


Figure 38.—Testing a welded joint.

holes IS NOT satisfactory. The piece should not break off short but should distort under the hammer blows to form an angle of at least 90° without cracking.

You can also tell quite a lot about the quality of a weld by simply LOOKING at it. You can check the smoothness of the bead, the amount of rein-

forcement (the seam should be at least 25 to 50 percent thicker than the base metal) and the cleanliness of the finished weld. Pits in the weld metal show you up as a mediocre welder. The weld CONTOUR should be even—it should be straight and its width and height should be consistently even.

This is not to say that a good-looking weld is ALWAYS a strong weld inside. But the reverse is usually true. A rough, pitted, uneven, weld surface practically always indicates a poor weld inside.

DANGER

Nobody is going to pin a medal on you if you court danger by using welding equipment in poor condition. Under ordinary conditions a welding outfit in good working order is as safe to operate as any other well-guarded tool. As a matter of fact, the standard for taking care of your welding equipment properly is that same respectful attitude mentioned earlier. As with any piece of machinery, neglect, misuse, and ignorance mean costly repairs. AND IN ADDITION, danger, not only to you but to others as well.

The MISBEHAVING REGULATOR can cause considerable trouble. The chief parts to get out of kilter in a regulator are the VALVES. Leaking valves will show up, for instance, by a gradual increase in pressure on the working gage of a regulator after you THOUGHT you had it adjusted. Or, suppose you have followed instructions carefully about being sure to fully release the adjusting screw so as to avoid damaging the low pressure gages. But even with the adjusting screw fully released, you notice that pressure is building up in the working gage. You can then assume that your welding outfit is afflicted with a disease called

"creeping regulators." The ailment is caused by worn or cracked seats in the regulator or by foreign matter getting stuck between the nozzle and the valve seat.

Repair leaking valves immediately or they will damage other parts of the regulator or apparatus. To repair a leaking valve, first take out and check the valve seat. If it is worn or damaged, replace it with a new one. If dirt has gotten into it, you should clean thoroughly the seat and nozzle. Any dirt in the valve chamber should also be blown out before you reassemble the valve.

The method you use to go about removing the valve seats from regulators depends partly on the make of the regulator. Some regulators are made so that you can get at the valve seat by using such simple tools as a vise and a screwdriver, while others require special tools.

Leaky valves are not the only parts of a regulator that can get out of whack. Broken or buckled gage tubes and distorted or buckled diaphragms are also responsible for a faulty regulator. These defects are usually caused by a backfire at the torch, by leaking regulator valves or by your own failure to release the adjusting screw on the regulator completely BEFORE opening the cylinder valves.

You can spot bad pressure gage tubes by the escape of gas from the pressure gage cases and by the irregular or wavering behavior of the pressure gage needle. The remedy for defective gage tubes is to replace the entire pressure gage. Be sure that it is the correct type and that you have a gastight fit. Only in CASES OF EXTREME EMERGENCY should pressure gages with bad tubes be repaired in an ordinary welding shop, because you need special tools. A bad gage is MUCH WORSE than no gage at all.

Buckled or distorted diaphragms in a pressure regulator also refuse to respond to adjustment. The only thing to do is to replace them with new ones. If the diaphragm is metal and is soldered to the valve case, it is necessary to take the regulator apart completely so that the soldering heat does not affect other working parts. This, you may be happy to know, is a job for the factory or a special repair shop—NOT for you.

If the diaphragm is rubber, you can easily replace it by removing the spring case from the regulator with a vise or a wrench.

TORCH TROUBLES are another problem in keeping welding equipment in working order. By now you should have been impressed with the fact that it is not healthy to treat a welding torch carelessly. That goes double for one in need of repair. Find out what is wrong with it and either correct the trouble immediately or take it out of service until the repairs can be made. These are some of the things that can go wrong.

Leaking valves.
Leaks in the mixing head seat.
Scratched or out-of-round welding tip openings.
Clogged tubes or tip.

If gas continues to flow after the torch needle valves are closed, you have leaking valves caused by worn valve needles, or damaged valve seats or perhaps a combination of both. If the valve NEEDLE is worn, take it out and put in a new one. If the valve SEAT is worn or otherwise damaged, you will have to reface or smooth down the seat to correct the trouble.

Leaks between the oxygen and acetylene inlet openings which lead to the mixing head are sometimes responsible for FLASHBACKS.

If a flashback occurs, the flame will "pop-out" nd is sometimes accompanied by a whistling ound. The torch may also become very hot. In uch a case the torch valves should be closed. Remember, flashbacks are caused by the tip becomng overheated, thus igniting the gas inside the ip; and the burning gases travel back through he torch toward the gas supply. Very often a lashback goes as far back as the regulators. Flashbacks may be of a serious nature and every precaution should be taken to avoid them.

Scratched or OUT-OF-ROUND WELDING TIP OPENINGS make it impossible for you to get a flame of the right shape even after thoroughly cleaning out the tip. The only thing to do in this case is to replace the faulty tip with a new one.

If you find that the flame is distorted and that it takes greater gas pressure than usual to produce the flame normally required for the size welding tip being used, you can assume that the TUBES AND TIP OF THE WELDING TORCH ARE CLOGGED. Such clogging is probably the result of carbon deposits from backfires or flashbacks in the torch—or perhaps dirt has gotten into the torch through the hose lines.

The remedy is to disconnect the torch from the hose and then blow out the hose to remove loose particles of dirt or foreign matter in it. Then remove the welding tip and clean it thoroughly by inserting a soft copper or brass wire, or a tip cleaner as in figure 39.

The same process which you used to clean out the welding tip can be used for cleaning the MIXING HEAD after you have disconnected it. But you must be careful not to enlarge the opening in the mixing head through which the gases enter. Then, to clean the TORCH TUBES of foreign matter,

remove both lengths of hose from the torch. Pick a large size welding tip, and attach it to the torch. Hold the end of the hose over the end of this tip and blow oxygen BACKWARD through the torch tubes at 20–30 pounds pressure, first with only the acetylene valve open and then with only

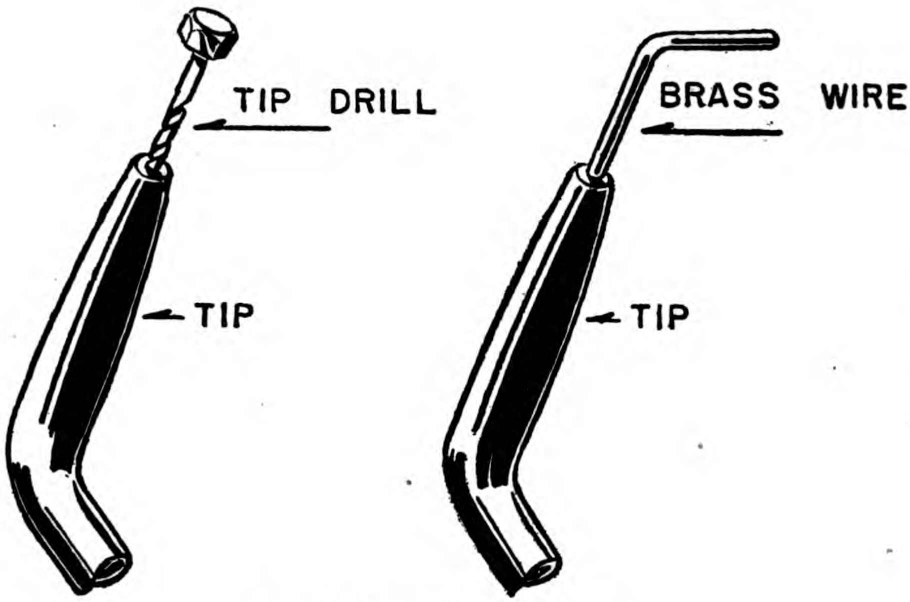


Figure 39.—Cleaning the tip.

the oxygen valve open. This is the ONE exception to the rule that you NEVER use oxygen as a cleaning jet. Oxygen is preferred in this case because ordinary air may contain considerable moisture and oil. Be sure all hose is disconnected from the torch.

Here are 12 commandments to observe in handling welding equipment—

Shut your torch off when you are not using it.

Close torch valves when the torch is not lighted.

Use only equipment which is IN GOOD WORKING ORDER.

Keep the flame away from contact with ANY PART of your welding equipment.

Use a sparklighter—NOT A MATCH—to light your torch.

Stand to ONE SIDE of the regulator when you open a cylinder valve.

Always check the regulator to see that the pressure adjusting screw is released before opening a cylinder valve.

Always use acetylene at pressures of less than 15 pounds.

Keep acetylene AWAY FROM oxygen, except in the torch.

In welding a container that has been used to hold a flammable substance—for instance, an oil drum—first clean it so thoroughly that no flammable solids, liquids, or vapors are present. To clean such containers run a stream of hot water (temperature not to exceed 150° F.) through the tank for one hour. The water should enter at the bottom of the container and overflow at the top. Every possible effort should be made to avoid a trapped air space within the tank. The flow should then be reversed for one hour. If hot water is not available, cold water may be used if the flow from bottom to top is continued for two hours—instead of one hour as when using hot water. This should be followed by circulating compressed air (low pressure) through the container for at least one hour and until all odor of fuel has disappeared. During all actual repair operations, a stream of low pressure air should be circulated through the container.

Make sure that hollow parts and jackete
containers have sufficient openings to allow
the escape of heated air as you weld them
If you forget to allow an escape for th
air, it will build up internal pressure as i
gets hot and expands.

Arrange for good ventilation when weldin
on brass, bronze, or galvanized iron.

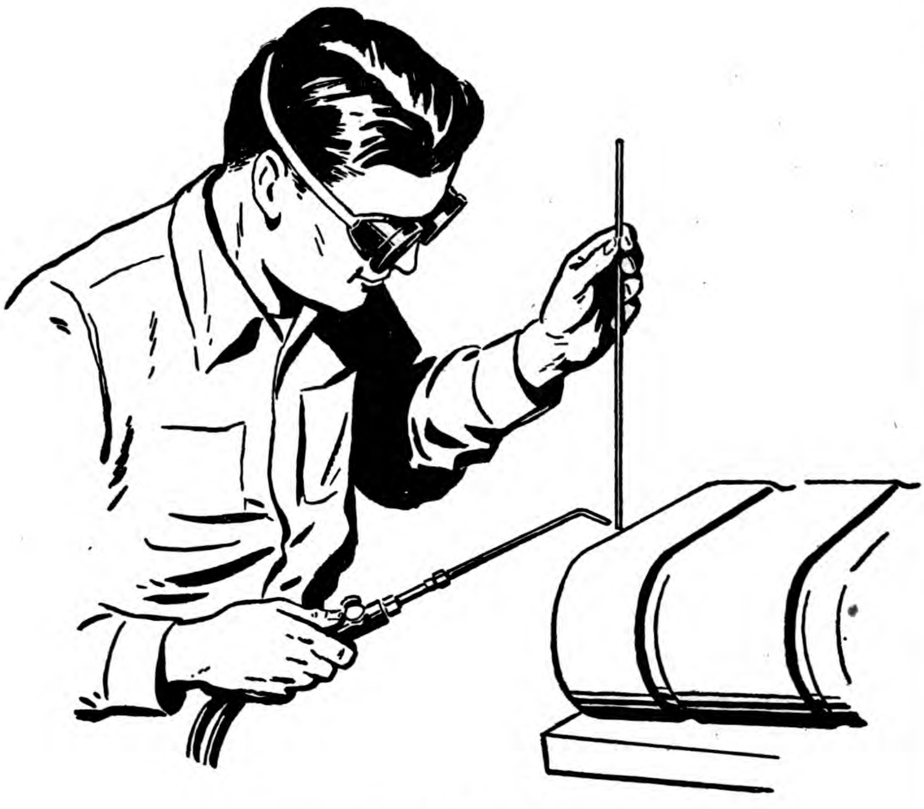


Figure 40.—Welding a container.

Oxygen does not burn, but it SUPPORTS COMBUS TION. This means that oxygen causes oil or sim ilar materials to burn fiercely. It also expand under heat and builds up dangerous pressures

Because of these characteristics of pure oxygen you should observe the following—

Keep oil and grease away from all oxygen fittings because oxygen under pressure coming in contact with grease may cause an explosion.

Store oxygen cylinders in a separate place apart from reserve stocks of acetylene or other fuel-gas cylinders.

Park oxygen cylinders out of the sun, and away from furnaces, radiators, or any other source of heat. Otherwise the heat will cause the gas to expand and build up dangerous pressures in the oxygen tanks. That means trouble!

Keep ALL OPEN FLAMES from contact with any part of the cylinder.

Handle oxygen cylinders carefully. They should not be dropped.

Oxygen from a cylinder must always be released through an oxygen regulator.

Use a light touch when you open oxygen cylinder valves. No wrenches or hammers.

Faulty oxygen cylinder valves should be replaced by the manufacturer. Don't try to repair them.

Here are six warnings for handling ACETYLENE—

Acetylene is a fuel and exposure to flame may cause the cylinder to catch on fire. Keep acetylene cylinders away from fire.

Always stand acetylene cylinders with the VALVE END UP.

Avoid rough handling, dropping, or knocking of acetylene cylinders.

Retire a leaking acetylene cylinder until it is fixed. DON'T try to use it.

Acetylene fuse plugs are your safety valves when the cylinder is exposed to excessive temperature. Leave them alone.

If a valve outlet of an acetylene cylinder becomes clogged with ice, thaw it with WARM water—NOT boiling water.

Now you know what your welding equipment is—how to set it up, what TO DO and what NOT to do when you use it. The other half of the story concerns the metals you work on. You have to know how to handle them and get along with them.

CHAPTER 3

TECHNIQUE FOR FERROUS METALS

WHAT YOU DO AND DON'T WELD

Repairing of aircraft parts by welding is done ONLY under certain conditions.

When the piece is made of NON-HEAT-TREATED METAL, or if heat-treated, when you are able to reheat-treat.

When the metal has NOT been cold-worked.

When the piece has NOT been brazed or soldered at its joints.

You cannot repair heat-treated aircraft parts by welding UNLESS you have facilities available for reheat-treating—and sometimes not even then, as in the case of aluminum alloys, if the part had also been cold-worked before welding. You never weld steel parts that depend upon cold-working for their strength because the heat of your welding flame destroys such strength. (Parts made of COLD-ROLLED STEEL which include streamline wires, cables, tie rods and solid drawn wire cannot be welded either.)

Steel parts with brazed or soldered joints are not to be oxyacetylene welded because the brazing

or soldering mixture penetrates the hot steel and spoils your weld.

Since heat-treatment and cold-working are both employed to give metals greater strength, you are right in suspecting that airplane designers make use of heat-treated and cold-worked metal a great deal, especially in structural members. You are also right in deducing from this fact that there are a lot of repair jobs on structural airplane parts that are out-of-bounds for a welder.

CLEAN IT UP

Suppose the answer to the three conditions—heat-treating, cold-working, and brazing or soldering—is such that welding can be used.

The first step in preparing an aircraft part for welding is to strip it of all dirt, grease or oil, as well as any protective coating it may possess, such as cadmium plating, enamel, paint, or varnish. Not only does such coating hamper your welding, but it gets into the weld and weakens it.

Cadmium plating can be chemically removed by dipping the edge to be welded in one of these solutions:

- A mixture of 73 cubic centimeters of hydrochloric acid, 27 cubic centimeters of water and 2 grams of antimony trioxide.
- A mixture of 1 pound of ammonia nitrate and 1 gallon of water.
- A mixture of 3 gallons of water, 7½ gallons of hydrochloric acid and 1½ pints of ammonia nitrate.

Enamel, paint, or varnish may be removed by buffing with a wire brush, by the application of emery cloth, sandblasting, using a paint or varnish solvent, or by treating the piece with a hot 10 per-

cent caustic soda solution. If you use either the solvent or the caustic soda method, you must follow it with a thorough washing with hot water to remove the solvent and residue.

Sandblasting is the most efficient way to remove rust or scale from steel parts. If dirt, grease, or oil is present, use a one-to-one carbon tetrachloride-naptha solution or a caustic soda solution. In a pinch you can use UNLEADED gasoline to remove grease or oil. Apply gasoline with a clean rag saturated with just enough gasoline to remove the film.

CARBON STEEL

The iron-carbon alloys may be classified into STEEL, which contains from 0.01 to 1.7 percent carbon, and CAST IRON, which contains from 1.7 to 4 percent carbon.

Practically all the weldable steels in aircraft construction, however, contain less than 0.50 percent carbon. There are a few exceptions, such as the high carbon fine steel wires which are resistance welded and then braided into cables, and some of the steel used in valves.

The technique you use to weld LOW AND MEDIUM CARBON STEEL is more or less basic, although chances are that you'll handle these in general shop work—not on aircraft. Welding high carbon steel and alloy steel—for example, stainless steel—requires a similar technique, but certain special precautions are necessary. You'll find out about these precautions in due time.

In general, low and medium carbon steel parts (the former contains from 0.10 to 0.30 percent carbon and the latter from 0.30 to 0.50 percent carbon) NEED NOT BE PREHEATED. You must clean the parts well, however, and also bevel down to a

45° angle each edge of joints on thick pieces. You DON'T NEED A FLUX. (Flux, in welding, is a chemical material or mixture, usually a powder, which is added to molten metal to remove oxides or prevent their formation in order to help make a sound union between the pieces to be joined.)

Pick out a FILLER ROD of LOW CARBON STEEL or soft iron which contains a small percentage of the metal vanadium.

Adjust the torch flame to neutral. AND, it is important that the flame stays neutral. The point is to avoid an oxidizing flame (one having an excess of oxygen) which burns or oxidizes the metal. When you burn the metal, a number of undesirable things happen. The molten weld pool becomes covered with a blanket of melted oxide of iron (iron plus oxygen), the fusion is poor, and small pockets of slag are left in the finished weld.

The best way to KEEP the flame neutral is to watch it continuously. Don't stand around wondering about your next leave, and then be surprised because you suddenly notice that an excess of oxygen or acetylene has crept into the welding flame. Slight variations in the pressure of the gases coming into the welding torch can easily spoil the one-to-one gas mixture of a neutral flame, UNLESS you are alert.

A good system for you to use at first for maintaining an exactly neutral flame is to stop to readjust it every 5 or 10 minutes. Draw your torch away from the weld pool just far enough to stop the melting process but NOT TOO FAR—the outer cone of the flame should still cover the weld area to protect it from the oxygen in the air. Now open the acetylene valve in the torch enough to give a clear excess of acetylene which you can

recognize as a feather around the inner cone. Then slowly close the acetylene valve until the feather has JUST vanished.

NOW TRY ONE

When you start welding the piece of steel, use the forehand method and hold your torch at a 60° angle to the surface of the work. The tip of the inner cone should not quite touch the molten metal.

If your piece of steel is COMPARATIVELY THICK—that is, plate steel rather than sheet steel—you must develop a swinging motion with your torch to make certain that the metal on each side of the groove melts thoroughly. As you swing the torch from side to side of the groove, the edges begin to break down and metal flows in the bottom of the groove.

While this process of breaking down the edges is going on, take the filler rod in your other hand and hold it in the outer cone of the torch flame to heat it. By the time the pool of molten steel has been formed at the bottom of the groove, the filler rod should be almost at the melting point.

Various torch and rod movements may be used in welding a joint, depending on the thickness of the metal and the type of joint to be welded. See page 30 of the previous chapter for torch movements. On heavier metals the oscillated torch and rod movements are preferred but on lighter metals a straightforward torch movement produces smoother and more uniform welds.

This filler rod motion must be made UNDER THE SURFACE of the molten pool. Never hold the tip of the rod ABOVE the surface so that it melts drop by drop into the pool.

Do you know what happens if you concentrate on the torch motion and forget about controlling the filler rod motion? At the first opportunity that your inattention provides, the filler rod leaves the molten puddle and sticks to the cooler metal at the sides of the groove. This makes it necessary for you to take time out to melt the filler off the side with the torch flame. It may take some time—and a certain amount of cussing—before you learn the trick of controlling the filler rod motion so that its tip is always free and in the molten puddle.

Assume, however, that you have the problem licked. Then as the weld proceeds, filler metal from the rod should be added until the surface of the joint is built up A LITTLE ABOVE the edge of the parts. This additional metal provides reinforcement.

The preceding explanation referred to thick pieces of low or medium carbon steel. But whether you are welding thin or thick pieces of steel, you must keep a sharp eye on the molten puddle. When it has been built up enough above the surface of the steel, GRADUALLY advance the puddle of molten steel along the seam until you reach the end. BE EXTREMELY CAREFUL, however, not to extend the pool of molten steel until the sides of the groove have been broken down by heat. The reason is elementary. Molten filler metal deposited on base metal that is hot but is still solid DOES NOT fuse. Instead of fusion, you have weld metal sticking to base metal somewhat like chewing gum—and about as firmly.

You may think, "That's not so hard." But getting good fusion is hard. The booby trap here is the fact that the iron oxide—scale—in steel melts slightly BEFORE the steel melts. And you may mistake it for molten steel. REMEMBER—a fusion

weld is not produced until THE STEEL ITSELF actually melts.

As you approach the end of the seam, raise your torch flame slightly, to chill the molten steel enough to prevent its spilling like water over the edge.

Learning to weld low carbon steel is like learning to smoke on corn silk—a first step. After a while, you get so that you can smoke a cigar and still keep your dinner down. The cigars of welding are the high carbon and stainless steels which are especially sensitive to variations in the welding torch flame.

The same welding principles apply for high carbon steel, but it is a good idea to practice welding low carbon steel until every weld is a perfect weld.

HIGH CARBON STEEL owes most of its special physical and mechanical characteristics to the comparatively high percentage of carbon in it—0.50. A welding flame with too much oxygen or too much acetylene will have a direct effect on the characteristics of the steel by changing its carbon content.

High carbon filler rods will help to maintain the hardness of steel which is to be heat treated for increased hardness and strength. Satisfactory results can be obtained with medium carbon filler rod on thinner sections when considerable intermingling of base metal and filler metal occurs. With the medium carbon rod, a weld of moderate strength and increased ductility can be obtained.

STAINLESS STEEL

Stainless steel, known to the trade as 18–8 CHROMIUM STEEL, is very strong and very ductile—which means it can be easily formed into intricate shapes—and it puts up a good battle against being

attacked by atmospheric conditions or eaten away by chemicals. Corrosion of a metal causes pits and irregularities. These flaws lower the metal's resistance to stresses caused by surface vibration, and bring about what is know as fatigue failure.

Welding stainless steel requires basically the same technique as welding ordinary steel. You have to take the same precautions—ONLY MORE SO. Particularly is this true with the types that have been treated or "stabilized" by the addition of the metal columbium or titanium. Such stabilizing means simply that a small amount of the metal columbium or titanium has been added to the stainless steel to NAIL DOWN the chromium. Without columbium or titanium, the carbon in stainless steel has an unpleasant habit of combining with the chromium at high temperatures and taking away some of the steel's "stainless" quality.

PRELIMINARIES

The "even more so" part of the precautions you must take in welding stainless steel starts with the WELDING FLAME. To avoid an oxidizing flame in welding 18–8 stainless steel, a slightly carburizing flame is recommended. By adjusting the flame so that the feathers around the inner cone are about $1/16$ inch long, you will get the right amount of excess acetylene.

In this way you protect yourself against any variations in gas pressure that might turn a strictly neutral flame into an oxidizing flame. You have to take special care to avoid a flame with too much oxygen because such a flame oxidizes the molten metal and makes it porous. But at the same time you make certain the flame doesn't have so MUCH excess acetylene that your stainless steel weld will be loaded up with carbon and lose its resistance to corrosion.

Use a TORCH TIP that is one or two sizes smaller than those used for similar gages of plain steel.

Another precaution is to use a FLUX especially compounded to dissolve the chromium oxide which forms on the molten stainless metal. Mix the flux with water until it forms a thin paste. Flux may also be mixed with alcohol and shellac. The flux is applied to the underside of the seam, and sometimes to the filler rod, although flux on the rod is not necessary. See figure 41.

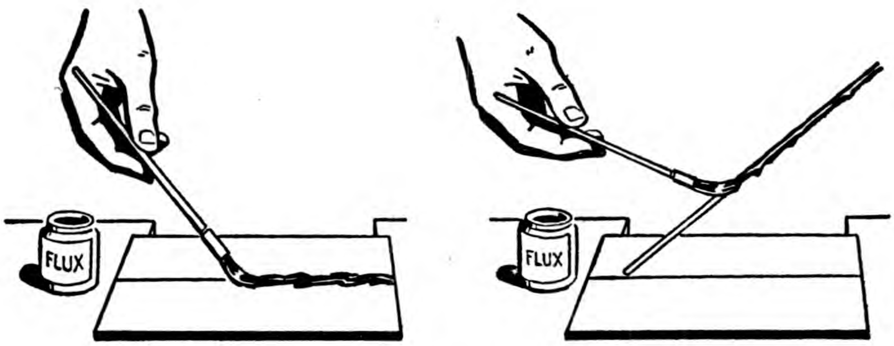


Figure 41.—Applying flux for a stainless steel weld.

The flux applied to the under side of the seam protects the hot metal from the air and consequently from oxidation. Let the flux dry a few minutes after you brush it on so that it becomes fairly solid before you begin welding.

Your filler rod should be of the same stainless steel as the base metal. If the base metal is columbium-treated, then you should pick a stainless steel filler rod which is columbium-treated. Use a filler rod whenever the pieces to be welded are $1/16$ inch or thicker.

If the pieces are thin—that is, up to $1/16$ inch thick—the common treatment is simply to turn up flanges on each edge to a height of about $1/16$ inch. Paint the flange with flux on both top and bottom and then melt them down to form a

smooth, moderately reinforced weld. You don't use filler rod in this case, because the flanges furnish enough metal to fill the seam.

If the parts to be welded are between $\frac{1}{16}$ and $\frac{1}{8}$ inch thick, join the edges in a PLAIN BUTT WELD. It is a good idea here to put a backing strip of copper underneath the seam to prevent the liquid metal from flowing out of the weld. If the parts are $\frac{1}{8}$ inch or thicker, you must bevel the edges to provide a "vee" to permit heat from your torch flame to penetrate all the way through the metal.

Still ANOTHER PRECAUTION which you should take is to guard against DISTORTION and WARPING, especially on thin stainless steel. Stainless steel has these disadvantages because it conducts heat only 40 percent as fast as ordinary steel. But, on the other hand, it expands 50 percent more than ordinary steel. Thus, because the heat is not rapidly conducted away, higher temperatures are reached in the comparatively small weld area. And, since the coefficient of expansion is high, there is a tendency toward greater distortion and residual stresses.

Clamps, copper plates to help chill the steel, and jigs—used either separately or in combinations—all help to hold the parts in line until your weld has cooled. In addition to holding the parts in line mechanically, they also hold them in line by helping conduct heat away from the weld, thus cooling the metal more rapidly.

Place the parts to be welded so that the line of the weld slants slightly DOWNWARD in the direction of the welding. In this way, the flux, which melts at a lower temperature than the steel, can flow forward and provide protection for the metal as it fuses.

But when do you start to weld? Just as soon as you check off these items.

Make sure your welding flame is adjusted to have a SLIGHT excess of acetylene.

Decide, according to the thickness of your metal, whether to make a flanged, plain butt, or beveled type of joint and thus whether to use a filler rod.

Paint a stainless steel flux on the joint and on the filler rod.

Choose the clamps and jigs you need to hold the parts in line and to prevent distortion from the heat of welding.

Planning ahead pays big dividends in this business.

NOW BEGIN

Whether you choose the forehand or backhand method of welding depends on how good you are at either method. In general though, forehand is better for thin sheet metal and backhand is better for heavier pieces.

Hold the filler rod ahead of your torch flame so that it melts in place or is melted at the same time as the base metal.

Use a SMALL welding flame to cut down the amount of heat put into the weld, both because the melting point of 18–8 is slightly lower than that of plain steel, and because of stainless steel's quality of poor heat conductivity. If you use more heat than necessary, it does not spread out through the piece—as was pointed out earlier—but instead sticks around the weld area and aggravates buckling. Another reason for using a small flame is that overheating causes the columbium in molten columbium-treated stainless steel to exit in a hurry by combining with carbon. By controlling the heat, you can keep down the loss of columbium to an amount which can be replaced by the columbium-treated filler rod.

Now your weld is well under way. You are being careful to hold the filler rod AHEAD of the flame. You are WATCHING the flame to see that it has a slight excess acetylene. You are keeping the flame small so as to avoid heating up the weld too much.

In fact, things are going along pretty smoothly, when you suddenly decide that what this job needs is a little stirring (known as puddling) to liven it up. That urge to stir is a SNARE AND A DELUSION—DON'T TRY IT. All you accomplish is the stirring in of air which increases the oxidation and the separation of valuable elements of the steel.

When you are working on stainless steel, weld from ONE SIDE ENTIRELY. If you start on the top, stick to it. Same goes for the bottom. Don't shift.

Be careful as you go along to fill the seam COMPLETELY with weld metal so that you don't have to go back and fix up some place that you should have finished as the weld progressed. Alternate heating and cooling is bad for steel. The steel oxidizes the minute you lift your torch flame from it and also warps because of its high expansion-contraction rate. Work so that you don't have to stop or retrace a hot weld.

If, however, it does become necessary for you to retrace a weld, wait until the weld cools entirely. Then preheat the entire seam before you apply the flame to any local area of the joint. Such preheating is NOT GOOD, because you're likely to warp the metal and also because the slow cooling that follows preheating causes the carbon in the steel to separate and then the weld corrodes.

In other words, if you want to save yourself a lot of trouble, complete your weld in one pass. ("Pass" means the layer of weld metal deposited

in one trip of the welding torch and rod down the length of the seam.) Get thorough, all-the-way-through, penetration of weld metal the FIRST time.

One more caution with regard to welding stainless steel—don't start at the EDGE of a seam and work in toward the center. If the joint you have to weld is in such a position that you must work in from an edge, the best policy is to start the weld at a point an inch or two in from the edge—NOT at the edge. Weld in from this starting point until that section of the seam is finished. Then return to your starting point and weld OUT to the edge to complete the weld. The reason for this procedure is to avoid excessive distortion.

Another steel alloy you have to know how to handle is CHROME-MOLYBDENUM—X-4130 is the code number. Chrome-moly, which is used in aircraft for fuselage and engine-mount tubing, is the steel on which you will do considerable repair work as an aircraft welder. Since tubing repair requires a special technique, it has been given a chapter of its own—Chapter 5.

TESTS

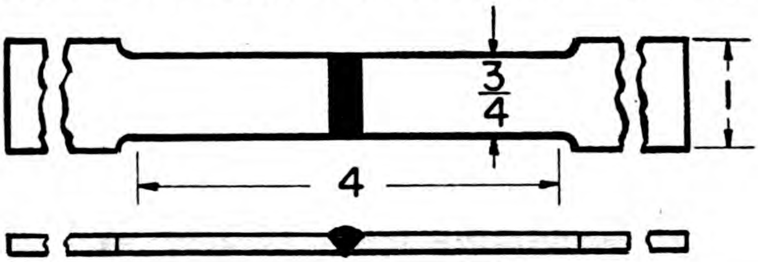
Before you can weld structural steel parts of Naval aircraft the Bureau of Aeronautics says that you HAVE to know how to make the following welds on either plain carbon steel or alloy steel.

There are five types of welded joints which are basic if you are to be allowed to weld steel—

- The open, single **V**, butt weld.
- The tubular butt weld.
- The vertical fillet weld.
- The horizontal fillet weld.
- The combination sheet and tube cluster fillet weld.

The first joint—the OPEN, SINGLE **V**, BUTT WELD shown in figure 42—tests both the strength of the

weld metal and your welding technique. The STRENGTH of weld metal is tested according to table II, which shows the tensile strength such a weld must have (depending upon the carbon content of the filler rod). Your welding TECHNIQUE—whether the metal is warped, and how much—comes in for scrutiny in the appearance of the base metal.



OPEN SINGLE V BUTT WELD (TENSILE TEST)
NUMBER OF SPECIMEN — 3
THICKNESS OF SHEET — 1/4"

Figure 42.—Open, single V, butt weld.

The weld which meets the requirements of tensile strength and welding technique must join two pieces of 1/4-inch sheet steel spaced 1/8 inch apart. The single **V** must make an included angle of 90°—that means that each side of the **V** has been beveled to a 45° angle.

You must build up the weld so that there is a top reinforcement which can be machined off before the weld is cut up for testing purposes.

Another weld on sheet steel which is part of the test is the VERTICAL FILLET WELD shown in figure 43. The bottom drawing shows suggested methods for arranging jigs to support the plates.

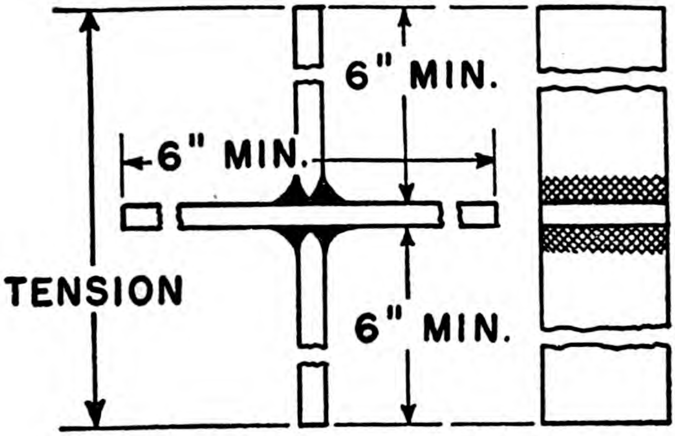
The plates for this joint must be of 1/4-inch sheet steel placed on edge during the welding operation. The jig which you use to support the weld must clear the table or bench as in figure 43. The hard part of this job is preheating your base metal with sufficient skill to obtain fusion in the CORNERS of the joint.

TABLE II

Tensile Strength of Weld Metal in Pounds per Square Inch

Filler Rod—percentage carbon content	Carbon Steel Base Metal	Alloy Steel Base Metal
Rod having up to 0.06 carbon content	45,000 lbs./sq. in.	55,000 lbs./sq. in.
Rod having from 0.07–0.12 carbon content	50,000 lbs./sq. in.	65,000 lbs./sq. in.
Rod having above 0.12 carbon content	55,000 lbs./sq. in.*	70,000 lbs./sq. in.*

*These values are to be obtained where alloy-steel filler rods are used.



FILLET WELD (TENSILE TEST)
NUMBER OF SPECIMEN — 2
THICKNESS OF SHEET — .025"

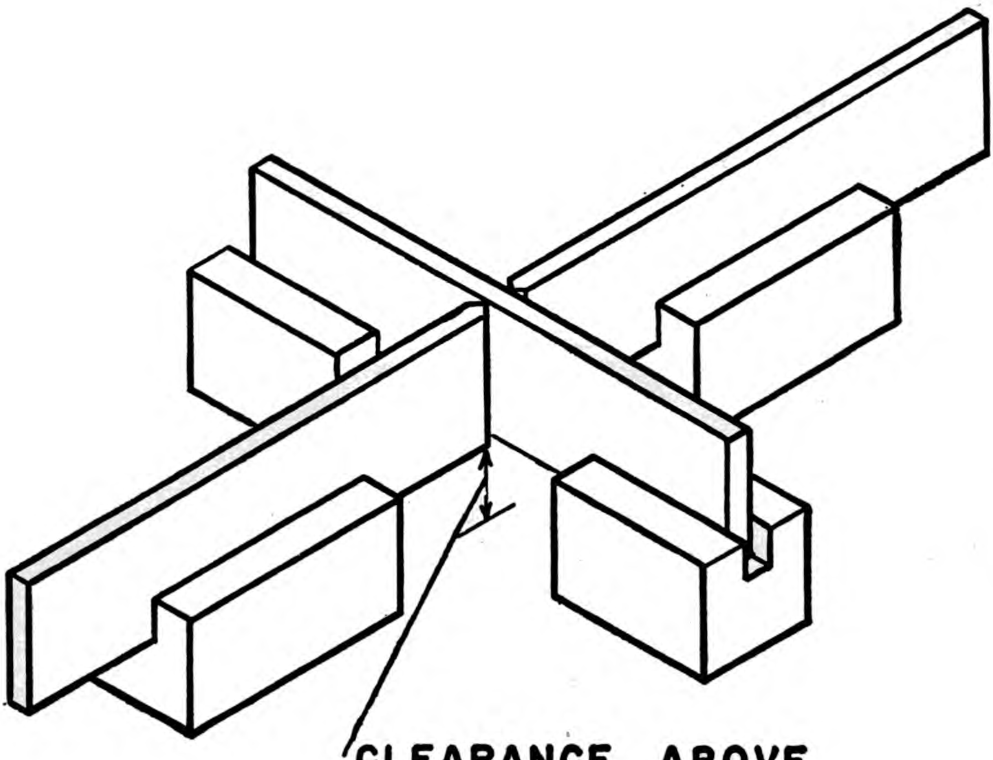
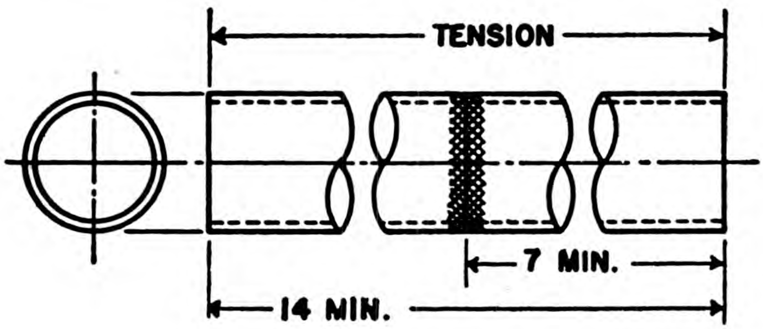


Figure 43.—Vertical fillet weld.

The vertical fillet weld must have a tensile strength of 10,000 pounds per square inch for plain carbon steel, 15,000 pounds per square inch for alloy steel. After the joint has been broken for testing of tensile strength the inspector will check closely on the extent of the fusion into the base metal. You had better be good. Penetration into the sides of the joint in aircraft welding, you remember, should be at least one-fourth of the thickness of the base metal, and in addition you should also obtain penetration all the way through to the root of the weld.

A TUBULAR BUTT WELD (see fig. 44) on tubing of 1-inch diameter and 0.028–0.065-inch wall



OPEN BUTT WELD (TENSILE TEST)
NO. OF SPECIMENS 4
DIA. OF TUBING 1
THICKNESS OF TUBING BETWEEN .028 & .065 INC.

Figure 44.—Tubular butt weld.

thickness, must have a tensile strength of not less than 50,000 pounds per square inch for plain carbon steel, and 80,000 pounds per square inch for alloy steel. The reinforcement on the joint may IN NO CASE be more than twice the wall thickness of the tubing.

You are required to make the tubular butt weld in three positions. First, horizontally on an ordinary bench. Second, vertically on a bench.

Third, in an overhead position not lower than eye-level. While welding the tubing in the overhead position, you are NOT allowed to rotate the tubing to make it easier for you to weld. If you can pass on this weld, you should have no diffi-

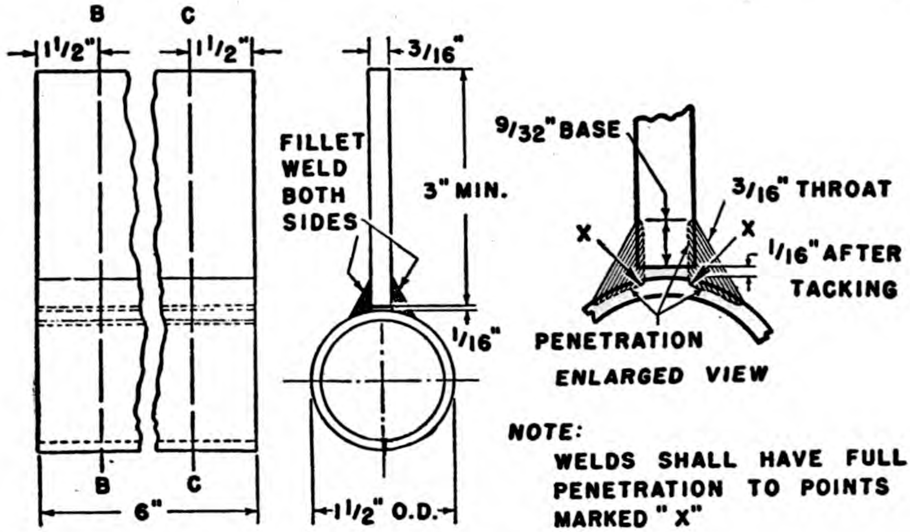


Figure 45.—Weld joining plate and tubing made in horizontal position.

culty in joining thin tubular parts in the positions normally encountered in an airplane fuselage.

Figure 45 shows a FILLET WELD made in a HORIZONTAL POSITION. And just to make it hard, the specifications call for welding PLATE to TUBING. This type of weld, according to most Aviation Metalsmiths, is the one where they really throw the book at you—the hardest of the lot. It isn't tested for tensile strength, but it IS rigidly tested for penetration.

The tubing for this test weld must be 1½ inches in outside diameter. The plate must be 3/16 inch thick. Clearance between the plate surface and tubing must be 1/16 inch AFTER TACKING. See figure 45. The weld must have a 3/16-inch throat and a 9/32-inch base.

Watch your penetration. You've got to have fusion to the points marked "X" in figure 45.

In addition, you must have complete and uniform fusion of weld to base metal at all points of contact.

Lack of fusion isn't the only thing which will disqualify you. The inspector will be equally UNIMPRESSED by laps, fissures, and gas pockets in the weld metal.

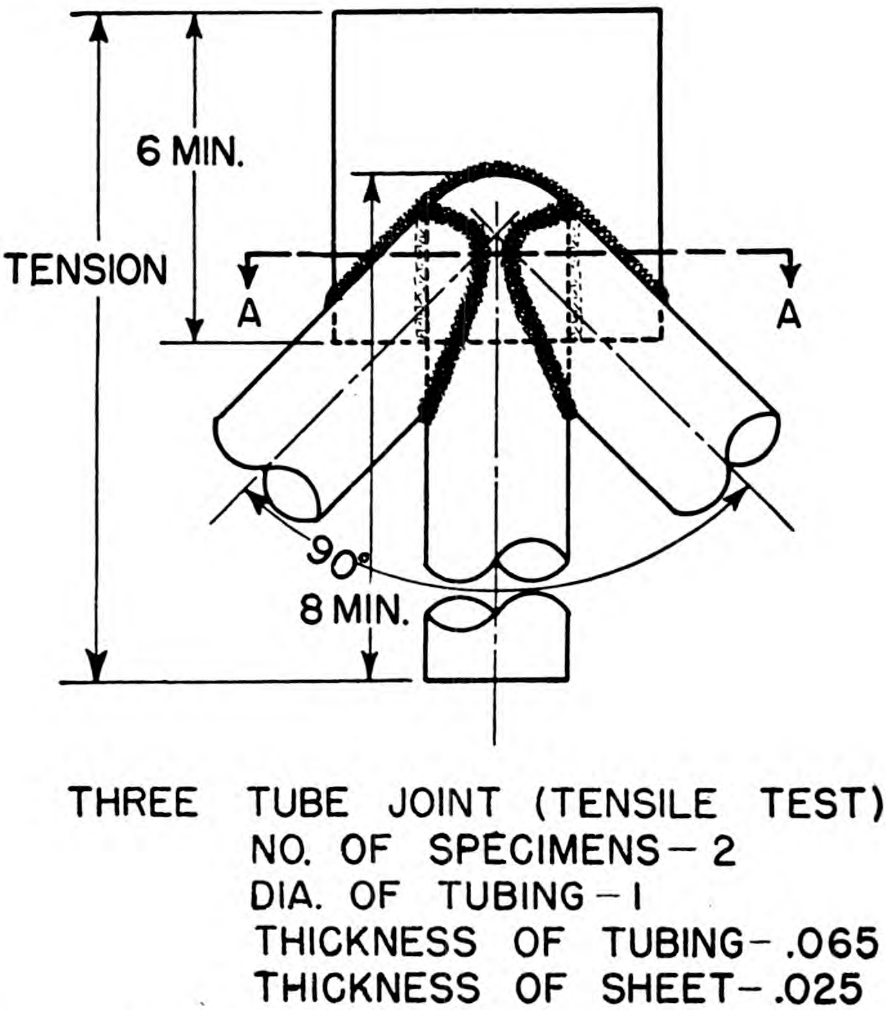


Figure 46.—Three-tube cluster joined to steel plate.

Another test weld on steel that you have to be able to do easily AND WELL, is one in which a CLUSTER OF THREE TUBES 1 inch in diameter and 0.065-inch in wall thickness is JOINED TO A PIECE OF SHEET STEEL 1/4 inch thick. Like in figure 46.

This kind of joint is designed to test your skill in joining light and heavy sections of metal. Your welded seam between plate and vertical tube must have a minimum TENSILE STRENGTH of 1,500 pounds per linear inch for plain carbon steel base metal, and 2,500 pounds per linear inch for alloy steel base metal. You must also, of course, obtain full uniform penetration of the weld metal. No blowholes or porous weld metal.

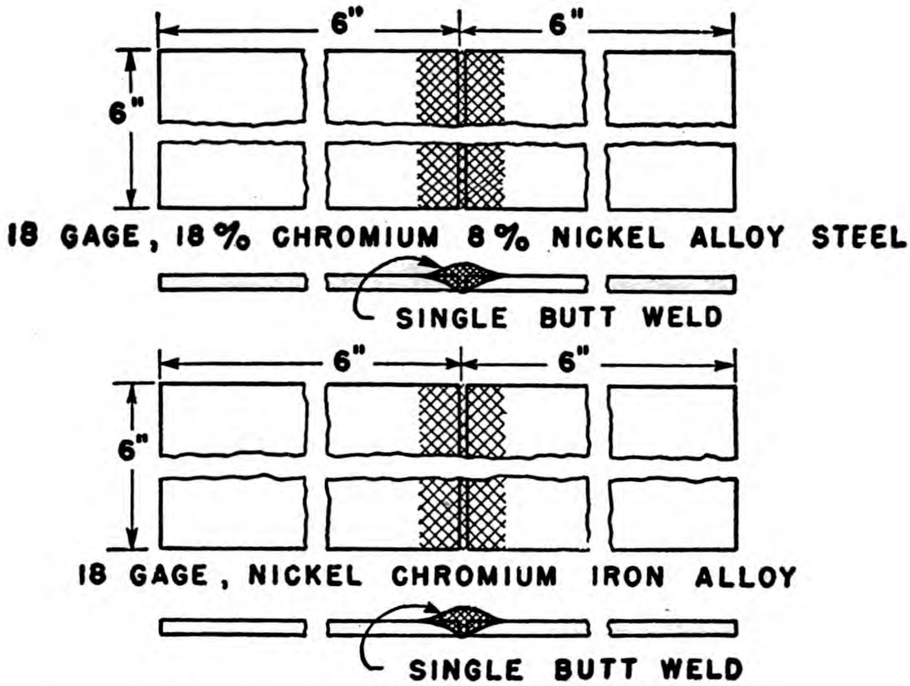


Figure 47.—Single, butt weld on corrosion-resisting and heat-resisting steels.

Because corrosion-resisting and heat-resisting steels require a slightly different welding technique from other kinds of steel, the Bureau of Aeronautics requires you to make two test welds of the SINGLE, BUTT type on 18–8 steel and on a nickel-chromium-iron alloy steel.

Your welds must join two thin sheets and two heavy sheets in such a manner that they will stand up under a bend test in which the weld is bent in a jig to a 180° angle. The weld on thin

sheets when bent 180°, must show no evidence of cracking EITHER in base metal or weld metal. For the weld on thick sheets, the bend test should produce cracks NO LONGER THAN 1/16 inch in any direction.

Figure 47 shows the type of weld you are expected to be able to make.

The welds are also cross-sectioned and inspected for penetration, fusion, blowholes, etc.

You may also be tested on welds made on actual aircraft parts made of 18–8 or of a nickel-chromium-iron steel.

CAST IRON

You don't have to weld cast iron in aircraft work, but you do need to know how to handle cast iron for general service work around the shop.

GRAY CAST IRON (iron containing 2.5 percent carbon) can be either fusion welded or bronze welded. For most cast-iron welding jobs, bronze welding is preferred, although fusion welding is necessary when the part to be welded must withstand temperature of 500° F., or more.

There are three things to remember in fusion welding of gray cast iron—

- It must be preheated to a dull red before welding.
- Use the correct welding rod.
- Cool the weld slowly.

First bevel the edges of a cast iron piece to form a 90° vee. On small parts you can do this with a hammer and cold chisel or with a grinding wheel. On large parts, you can cut the vee with a pneumatic chipping hammer or with a cutting tip on your welding torch.

In beveling ordinary thicknesses of cast iron you need extend the vee only to within 1/8 inch of the bottom of the break. This blunt bevel makes it

easier for you to control the molten cast iron and lessens the danger of your burning a hole through the bottom. Carbon blocks may also be placed under the weld to prevent molten cast iron from running through.

After the joint is beveled, remove all grease, slag, rust, and dirt for an inch back from the edges by using an emery wheel, sandblast, wire brush, or cold chisel. If you don't have a perfectly clean joint, there will be porous spots and blowholes in the weld.

PREHEATING the casting insures that the expansion-contraction stresses will be equalized. Gray cast iron is very brittle and sensitive to changes in temperature. If you heat up one part of a casting in welding it, while the rest of the piece remains cold, the metal will crack. Preheating the whole piece gets around this difficulty. Whether it is possible to confine the preheating to the section around the break, depends upon the size and shape of the casting and the location of the break. You can preheat small parts with your torch flame. Larger parts should be put in a furnace. In either case, the metal should be heated to a dull red and KEPT at that temperature during welding.

The WELDING ROD should be of a special chemical composition which will put certain elements back in the weld metal, particularly silicon, which tend to burn out during welding. Check your filler rod to see that it is one intended to be used on cast iron.

You also need a FLUX to break up the coating of slag which forms on the surface of the molten cast iron. Dip your filler rod in the can of dry flux after first heating the rod slightly in the torch flame. In this way the flux can be introduced GRADUALLY into the molten weld pool. A good

flux for cast iron is one having equal parts of carbonate of soda and bicarbonate of soda.

Use a WELDING TIP of one size larger than for steel of the same thickness.

START WELDING

Now that you have cleaned, beveled, and preheated your piece of metal, the next step is to adjust your torch flame to EXACTLY NEUTRAL. Then take the torch in one hand, the filler rod in the other, and start. Direct the cone of the flame at the bottom of the groove about $\frac{1}{8}$ inch from the surface. When the bottom of the vee is melted thoroughly, use a constant, circular motion of the torch to melt the beveled sides of the vee until they begin to run down and combine with the molten puddle at the bottom of the groove. Keep moving the torch from side to side to make sure both sides as well as the bottom are melted. The torch motion is much like that used in welding steel plate. Now take the filler rod, hold it near the flame to heat it, dip it in the flux, place it just below the surface of the molten puddle and KEEP IT THERE, as in figure 48.

You will notice that as the filler rod melts into the puddle, the level of the molten metal rises in the groove. Keep a sharp eye on this molten puddle and when it has been built up slightly above the top surface of the base metal, move your torch flame forward. Be careful to melt the sides of the vee AHEAD of the advancing puddle so that molten metal is NEVER forced ahead onto colder metal.

Every once in a while stir the molten pool gently and skim off with the filler rod any impurities which may be floating on top. But DON'T keep dipping the rod in and out of the pool con-

stantly. Continue adding flux to the filler rod from time to time.

When gas bubbles or white spots appear in the molten pool or at the edges, you must add flux and play the torch flame around the spot until the impurities float to the top. You can skim these impurities from the weld with the filler rod

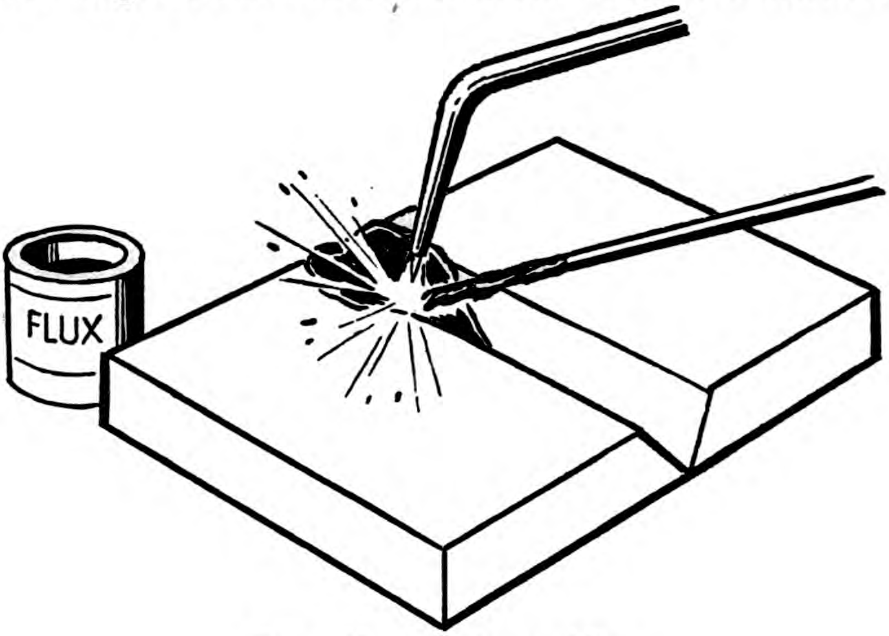


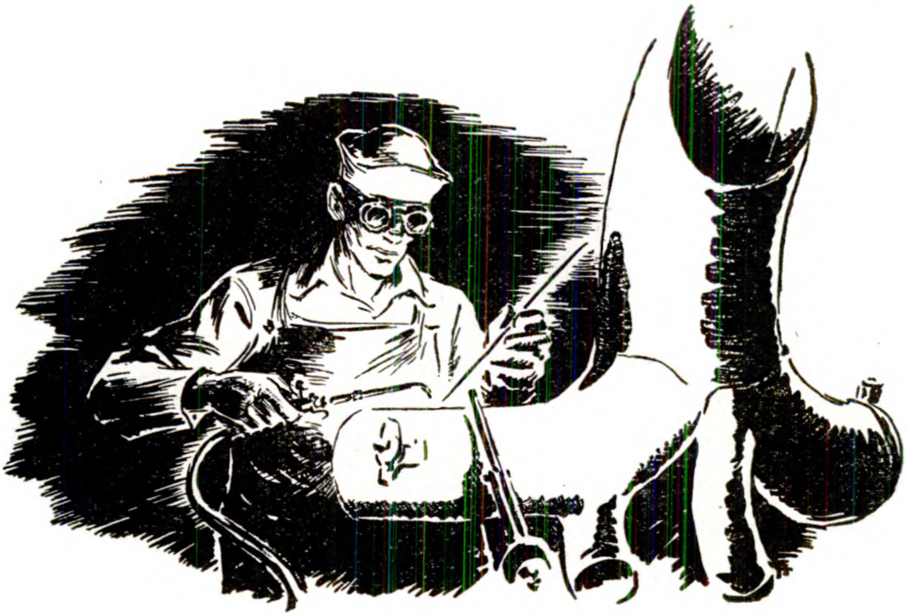
Figure 48.—Cast iron welding.

and then eliminate them entirely by tapping the hot rod against the table.

Cast-iron welding should be done as fast as possible. When you have completed a weld, cover the part with a piece of asbestos paper to enable it to cool SLOWLY.

WROUGHT IRON

Welding WROUGHT IRON is about like welding steel. Prepare the parts and then preheat them slightly. Use a NEUTRAL torch FLAME. The filler rod should be of wrought iron or low carbon steel. FLUX is not necessary because the heat needed to melt wrought iron is great enough to destroy any products of oxidation that might put in an appearance.



CHAPTER 4

TECHNIQUE WITH NONFERROUS METALS

ALLOYS YOU'LL ENCOUNTER

Nonferrous metal, in everyday language, means a metal NOT made from iron ore. Aircraft are made chiefly of these nonferrous metals and their alloys, because they are strong AND LIGHT. The lighter the airplane, as you are well aware, the greater the ease with which it flies through the air.

Most important of these nonferrous metals of which airplanes are made today are the ALUMINUM ALLOYS. Others are the MAGNESIUM ALLOYS and the nickel-based alloys, INCONEL and MONEL (not strictly nonferrous metals).

Before you begin reading about how to weld them, check back to the beginning of Chapter 2 and review the rules given there concerning what you DO and DON'T WELD on aircraft nonferrous metals. Also, look again at the instructions for

removing protective coatings, dirt, grease, and oil from aircraft parts which you want to weld.

ALUMINUM

Commercially pure aluminum is a silver-white, lustrous metal that is noted for its lightness—it is only about one-third as heavy as steel. It has a high degree of resistance to corrosion and can be easily formed into intricate shapes. In the wrought form it is called grade 2S (the S indicates that the metal is wrought).

The one virtue that pure aluminum does not have is strength. Aircraft parts must be strong as well as light. The aluminum manufacturers have met this problem. By adding one or more other metals to the pure aluminum, they have developed alloys which are both LIGHT AND STRONG.

These alloys, which come in either cast or wrought forms, can be made still stronger and harder by WORK-HARDENING—that is, by rolling, forming, pressing, or otherwise cold-working the metal. Since the hardness depends on the amount of cold work done, some of the wrought-aluminum alloys are available in several work-hardened tempers—either ¼ hard, ½ hard, ¾ hard, or hard. The ½ hard temper of aluminum sheet is the one you find most often used in aircraft parts.

To add even greater strength, aluminum alloys are heat-treated, a process of controlled heating and cooling of the metal. With but minor exceptions, ALUMINUM ALLOYS USED FOR STRUCTURAL MEMBERS IN AIRCRAFT ARE HEAT-TREATED. The principal aluminum alloy thus used is 24S. Some of the other heat-treatable alloys used for structural parts of aircraft are A51S, 17S, 53S, 61S, and 11S. These code numbers refer to the kind and amount of alloying metals which are added

to the aluminum to give it certain qualities of strength and hardness. The total amount of alloying elements is seldom more than 6 percent in the wrought forms. Cast forms, however, may contain somewhat higher percentages of alloying metals.

NON-HEAT-TREATABLE ALLOYS used for parts in aircraft which are not subjected to great stress, such as tanks and fuel lines, include 2S, 3S, and 52S. A cast alloy, 43, is used for many nonstructural fittings.

In general, you do VERY LITTLE welding of aluminum aircraft parts, because the great majority of them are made of heat-treated metal.

You are not allowed to weld STRUCTURAL PARTS made of heat-treated aluminum alloys. Even if you had facilities for reheat-treating these parts after welding, you still could not increase the strength of your weld enough to stand up to the stresses which these parts must bear. Remember, the use of torch welding in aircraft is limited to places where high unit stresses ARE NOT INVOLVED and, consequently, where heat-treated metal IS NOT USED.

You must know how to weld aluminum alloys, even though the occasions when you will be called upon to do it may be infrequent, just as it is a good idea to know how to swim, even if your ship never runs into trouble. One common application of torch welding on aluminum and aluminum alloys in aircraft is in welding tanks. Torch welding is the simplest way to obtain gastight or liquid-tight seams in such tanks.

Although aluminum is one of the most weldable of all metals, it does have certain distinct characteristics of its own which you must take into account before you can turn out consistently good welds.

CONSIDER THE JOINT

As in welding any other metal, the first step is to CLEAN UP THE JOINT. Use a wire brush or steel wool on the edges which you are going to join until you obtain a dull-white, nonreflecting surface. If there is considerable corrosion, the joint should be cleaned by dipping it from 10 to 30 seconds in a hot solution of 10 percent caustic soda or 10 percent trisodium phosphate. Then rinse in a dilute 10 percent nitric-acid solution followed by hot water to remove all traces of the cleaning solution because they tend to corrode the metal.

The KINDS OF JOINTS you use—whether butt, tee, edge, or corner—are the same, in general, as those you learned to make on steel.

Butt joint welds on sheet aluminum alloy should be of the flange type—if your piece is .081 inch or thinner, and if it is possible to bend up flanges on the edges. Flanged joints should be clamped together and then tack-welded to hold them in alinement while you weld.

Tack-welding means making short welds at various spots along the welding line in order to hold the pieces in place until the actual welding is under way and there is no longer any danger that the pieces will shift position.

An ordinary butt joint like the one in figure 49 may be used when your piece is between .081- and .125-inch thick. Heavier sheets should be beveled and notched as in figure 49. Notch the edges of the joint with a cold chisel about $1/16$ inch deep and $3/16$ inch apart. These notches act as expansion joints to help control the expansion caused by the heat of your torch, and they also help the flux penetrate the seam thoroughly.

After you have cleaned and prepared the joint,

you must decide whether to preheat the piece. Aluminum sheets $\frac{3}{8}$ inch or thicker, as well as larger aluminum castings, should be PREHEATED to 700° to 800° F. This preheating avoids heat strains and reduces the amount of welding gas

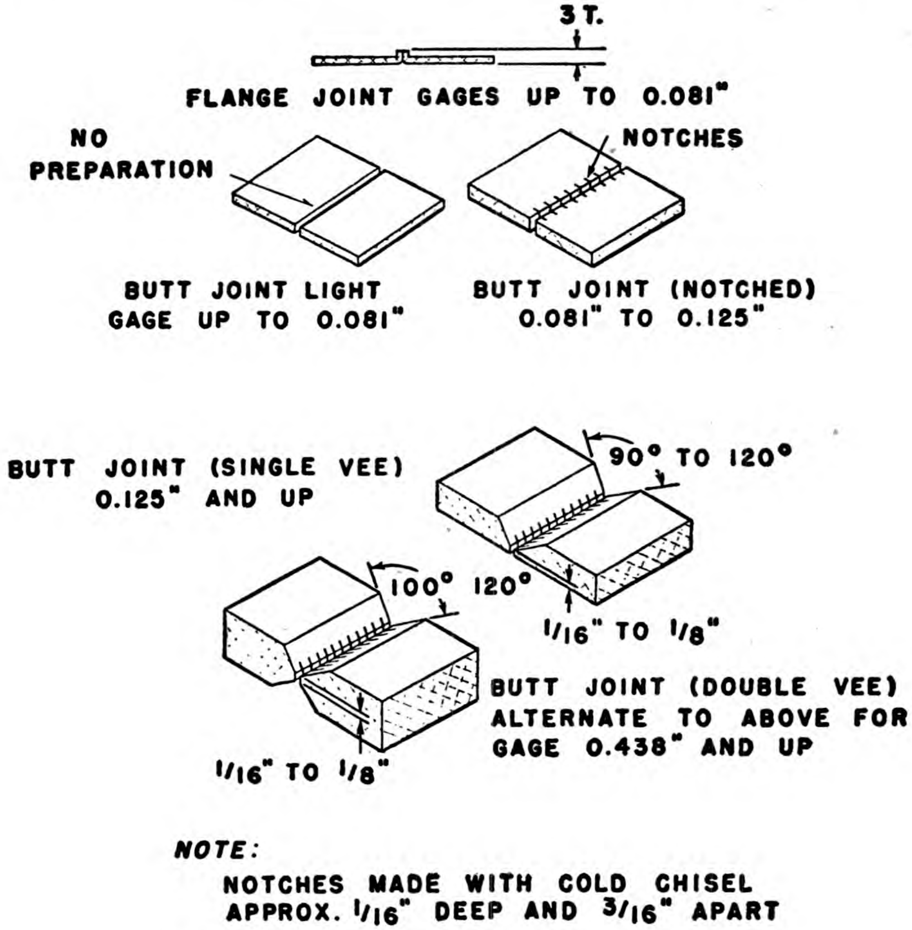


Figure 49.—Butt joints for aluminum welding.

necessary to melt the seam. Such preheating is needed, of course, because aluminum conducts heat and expands so easily. By preheating, you have the aluminum base metal at a temperature just SLIGHTLY under its melting point, in the area around your seam, before you apply the welding flame. Therefore, the additional expansion is likely to be small. You also cut down the distortion, and the result is a sound, strong weld.

Castings, particularly, require careful preheating to prevent serious cracking. Small castings can be preheated with the torch, but you must put larger ones in a furnace. NEVER preheat aluminum alloys to a temperature higher than 800°. If you do, the heat may melt some of the alloys, and you then have "burned" metal.

PICK THE RIGHT ROD

Picking the right filler rod is as important with aluminum as with any other metal. Non-heat-treated 2S and 3S take a 2S filler rod. For 52S and 61S a filler rod containing 95 percent aluminum and 5 percent silicon (43S is the code number) is best.

Welding rods are available in 1/16, 1/8, 3/16, and 1/4 inch diameters. The usual rule is to match the size rod to the thickness of your base metal.

Since aluminum is such a good conductor of heat, it is smart to choose a WELDING TIP of a size slightly larger than one you would choose for steel of the same thickness in order to get enough heat concentration to melt the base metal. Table III shows the recommended sizes of tips and amounts of gas pressures for welding aluminum of varying thicknesses.

The welding flame for aluminum work should be adusted to neutral. Some folks say to have a slight excess of acetylene in the flame. But usually you'll find that a neutral flame (one-to-one mixture of oxygen and acetylene) will serve best.

The flame should be soft—not "blowy"—which means you must adjust the needle valves on the torch so that the gas mixture comes into the welding tip at a low speed.

Flux for aluminum comes in powder form and is usually mixed with water to form a thin paste

TABLE III

Approximate Size of Tips and Relative Gas Pressures Used in Welding Aluminum of Different Thicknesses

Metal Thickness B & S Gage	Oxyhydrogen			Oxyacetylene		
	Diameter of Orifice in Tip, Inch	Oxygen Pressure, lb/sq. in.	Hydrogen Pressure, lb./sq. in.	Diameter of Orifice in Tip, Inch	Oxygen Pressure, lb./sq./in.	Acetylene Pressure, lb./sq. in.
24–22	0.035	1	1	0.025	1	1
20–18	.045	1	1	.035	1	1
16–14	.065	2	1	.055	2	2
12–10	.075	2	1	.065	3	3
1/8–3/16	.095	3	2	.075	4	4
1/4	.105	4	2	.085	5	5
5/16	.115	4	2	.085	5	5
3/8	.125	5	3	.095	6	6
5/8	.150	8	6	.105	7	7

(2 parts of flux to 1 part water). This flux has a lower melting point than either aluminum or its oxide, which is always present on the surface. Thus the flux, by melting first, breaks down and carries off the oxide skin, allowing liquid filler metal to flow into clean, molten base metal.

If your particular job does not require using a filler rod, then paint the flux directly on the joint. If you use a filler rod, coat it with flux too. On thick sections of aluminum, you should coat BOTH the metal and the filler rod.

Before welding, check off these points on the list of preliminaries.

Is the joint clean and properly prepared?
Is it preheated (if that is necessary)?
Have you picked the right filler rod?
Have you applied the flux?

TRY IT

Only when you have taken these steps, are you ready to begin.

Hold your torch at a considerable slant so that it doesn't blow holes through the metal. An angle of about 45° to the surface of the base metal is about right for flanged and butt joints. In welding a tee joint, hold the flame midway between the two pieces. The inner cone of the flame should be about 1/8 inch from the metal but must NEVER touch the metal.

You must take considerable care to heat both edges of the joint evenly so that the heat will be well spread around in the weld area. Don't hold the torch too long on one spot. If you do, aluminum conducts heat so well that there is danger that the whole area around the weld will crumble and fall away.

If you are using a filler rod, the tip of the rod should be kept in the pool of molten metal and should be melted into the weld UNDER THE SURFACE of the pool. Do not stir the puddle or push the rod through it. Be careful to see that the filler metal enters the weld ONLY where the base metal has been brought to a molten condition. It is as great a sin against aluminum as against any other metal to allow filler metal to flow ahead onto the relatively cool and unfused edges of a seam.

NO COLOR CHANGE

The problem of deciding just when the edges have reached their melting point is complicated, in the case of aluminum welding, by the fact that there is no radical COLOR CHANGE when the melting point is reached. The aluminum may be solid one instant and then, without any change in appearance, melt and sag.

Light blue glasses will help you "see" the light gray color of the metal just as it is melting. You can also "feel" the change coming by lightly touching the surface of the metal with the filler rod.

Aluminum begins to feel soft and elastic just as it starts to melt. The instant that this "feel" indicates that the melting point is approaching dip the filler rod tip into the puddle and permit it to melt with the metal. In figure 50 you can see a diagram of the dipping motion your filler rod should take as you heat the metal.

In (*A*) of figure 50, the metal is being heated. In (*B*) the base metal is starting to melt. In (*C*) the filler rod is dipped into the molten puddle and allowed to melt with it. In (*D*) the filler rod is being lifted while the torch flame is moved for-

ward to continue the melting. In (*E*) the filler rod dipping process is being repeated. (*F*) shows the continuous dipping motion of the filler rod as you progress along the seam.

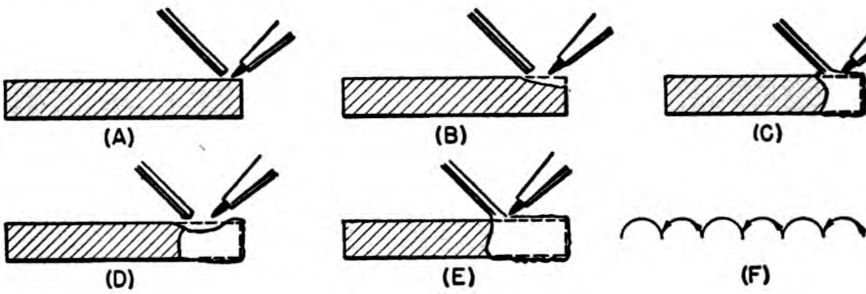


Figure 50.—Proper filler rod motion in welding sheet aluminum.

Another difficulty in welding aluminum is that it solidifies very quickly after it has been melted. You can't make the molten metal flow as you can molten steel. With practice, however, you'll be able to get good fusion, build up the weld to the right height, and produce a smooth, even ripple with very little trouble. You may even find it EASIER to weld than steel, once you have the knack.

To melt the filler rod in welding aluminum, you have to hold it ALMOST IN the torch flame before dipping it into the molten pool because the heat of the molten aluminum pool is not high enough to melt the rod.

You must work rapidly. Otherwise, you can hardly help holding the flame in contact with molten metal at some point or other. If that happens, don't be surprised to see that you've burned holes right through the metal. A good butt weld in aluminum sheet will show a bead on BOTH top and under sides of the seam.

When you have finished the weld, you must wash away all traces of flux that may be left sticking to the surface. Otherwise, if moisture is present, the elements in the flux will attack the

base metal and corrode it. To remove the flux, simply scrub the piece in hot water. Or if the weld is located where it is hard to reach with hot water and a scrub, dunk it in a cold 10 percent sulphuric acid bath.

MORE TESTS

As in the case of ferrous metals, the Bureau of Aeronautics requires you to pass certain qualification tests before you can weld aluminum.

There are three kinds of welds with aluminum sheet which you have to do well enough to qualify.

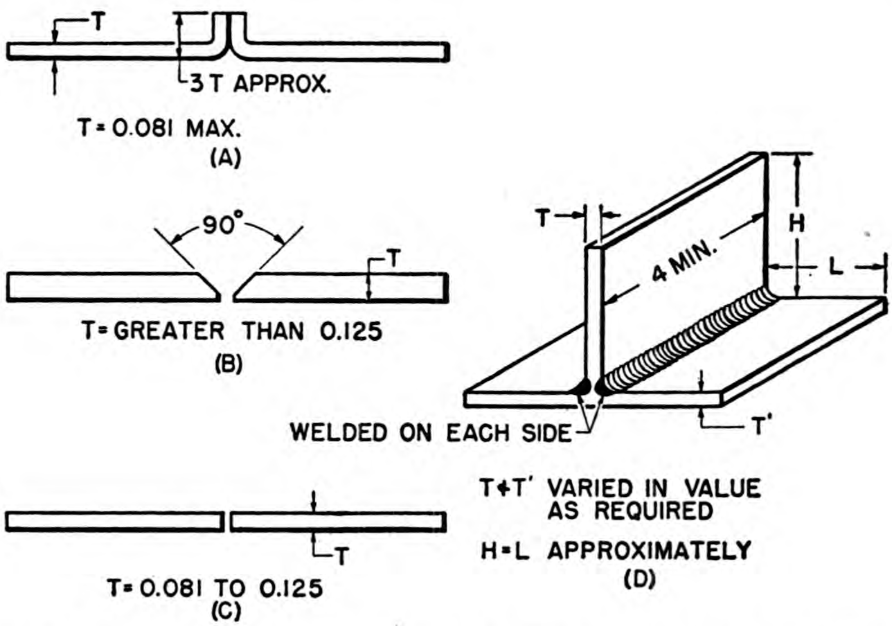


Figure 51.—Welding samples of flanged, butt, and fillet joints on aluminum sheet.

They are the flanged joint on metal 0.081 inch thick like (*A*) of figure 51, the butt joint on metal from 0.081 to more than 0.125 inch like (*B*) and (*C*) of figure 51 and the fillet T joint as in (*D*) of figure 51.

The flanged joint is made on aluminum sheet pieces approximately 6 inches square. The

height of the flanges turned up should be about twice the thickness of the sheets. You clamp these flanges together at first, but the edges should then be tack-welded to preserve their alinement. Then melt down the flanges—add welding rod and flux as necessary.

Your weld should show a smooth, well-rounded bead on both sides of the joint with little or no evidence to show that the sheets were flanged.

Thicknesses of metal between 0.081 and 0.125 inch need not be beveled or flanged. Their normal square shape is O. K. For the butt joint in sheet aluminum of MORE THAN 0.125-inch thickness, you must bevel the edges at 45° angles to form an included angle of approximately 90° as in (*B*) of figure 51.

A T fillet weld, approximately 4 inches long, will be required of you. You'll be smart to be prepared to tackle the MOST UNFAVORABLE combinations in thickness of the two plates which an inspector can think up.

Each of these joints is cross-sectioned by the inspector and then carefully checked for unevenness, undue roughness, cracks, blowholes, lack of penetration, lack of fusion, and so forth.

The flange-welded joint of aluminum on a non-heat-treatable alloy, must withstand a bend test of 180°—that is, the metal is bent completely back on itself along the line of the welded joint—without showing cracks in either base or weld metal.

In special cases when you are tested on welding heat-treated aluminum alloys you are required to make a sample butt weld like that in figure 42 for steel. Such a weld must pass a TENSILE STRENGTH TEST and show strength of at least 80 percent of **THE STRENGTH OF THE HEAT-TREATED BASE METAL.**

After you have caught on to welding sheet aluminum, you'll discover that welding ALUMINUM CASTINGS is more of the same.

Castings, however, are likely to be of fairly complicated design and the thickness of the aluminum in them will probably vary from section to section. These two characteristics mean that aluminum castings are considerably more allergic (susceptible) to heat strains and to cracking. Also, many castings are HEAT-TREATED for added strength. Welding such heat-treated castings tends to destroy the effect of the heat-treatment. Consequently, unless you have facilities for reheat-treating such castings AFTER WELDING, you had better leave well enough alone.

Before you weld a broken aluminum casting, the first thing to do is CLEAN IT CAREFULLY with a wire brush and gasoline to take off every trace of oil, grease, and dirt.

Edges of sections heavier than about $\frac{3}{16}$ inch should be beveled at about 45° by mechanical means. Such tooling can usually be taken care of on thinner sections if necessary by means of your torch and—new word—PUDDLING ROD.

A puddling rod is a gadget which is used in welding aluminum castings to break up the oxide in the weld metal. If you look at figure 52 you will see three puddling rods with ends of varying shapes. They are made from pieces of $\frac{1}{4}$-inch steel welding rod about a foot long. One end is heated with the torch and flattened to a width of about $\frac{3}{8}$ inch. Then that end is ground smooth, and the other end is bent over to form a handle.

To bevel a vee, when you are repairing a cracked casting, heat a section of the crack for about 2 inches by brushing the flame back and

forth over it. Keep the flame about 2 inches from your metal and move it freely so that no one spot becomes very hot. YOU DON'T WANT TO MELT THE METAL.

In a few seconds, the metal will become hot enough so that you can use the flattened end of the puddling rod to scrape out a vee reaching to the bottom of the seam. As you proceed, knock

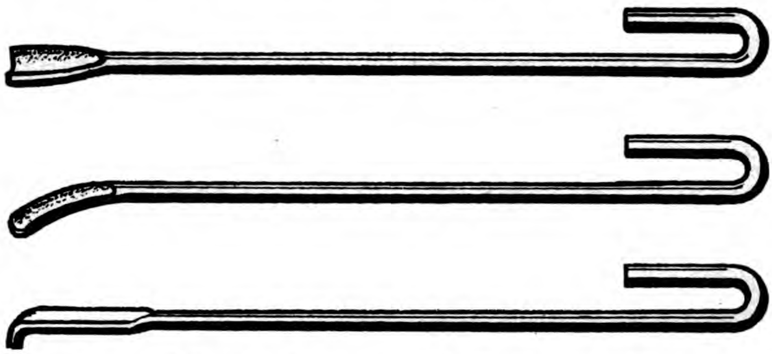


Figure 52.—Puddling rods for aluminum welding.

off the metal and oxide which collects on the puddling rod by tapping it against the table. Keep the puddling rod out of the flame. You DO NOT want it to get red hot.

If you have to repair a broken casting, be sure all unsoundness around the crack is melted or cut away before you start welding. Line up the broken part and then use light iron bars and clamps to hold it in the right position for PRE-HEATING and welding. Fasten the clamps snugly, but not so snugly that they strain any part of the casting—especially any thin sections. Aluminum, when hot, is VERY WEAK and will crumble under what would ordinarily be only slight strains. You should be careful also, to see that the clamps are drawn up so as to allow the casting to expand as much as it wants to during the heating.

If the casting is a big one or has a lot of intricate sections, preheat it slowly and evenly in

a furnace. If it is small, or if the break is near the edge and in a thin section, you can preheat the area immediately around the break with a torch flame. In any case, remember that CAST ALUMINUM SHOULD BE HEATED SLOWLY. Otherwise, cracks will appear in the part of the casting near the flame.

After the broken casting has been prepared and preheated, you are ready to TACK WELD the edges of the crack. When the tacks are finished, start welding IN THE MIDDLE of the seam and weld out toward the ends. Like sheet aluminum, cast aluminum melts at a comparatively low temperature and the heat of the molten weld pool IS NOT great enough to melt your filler rod. As you weld, hold the rod almost in the torch flame in order to melt it. For ordinary castings an aluminum-copper-silicon rod is used.

Flux is necessary in welding aluminum castings to float the aluminum oxide to the surface. The tough oxide film can be BROKEN UP by the action of your puddling rod. But unless flux is present, the oxide skin which you have broken up by puddling may remain in the weld. Oxide, you remember, makes for poor fusion and a weak-sister weld.

The best way to be absolutely certain your weld is clean as a new penny is to turn the molten metal THOROUGHLY with the end of the filler rod or the puddling rod, and be sure the filler metal is completely melted. Thus the flux and oxide are worked to the surface of the weld, and you don't have to worry about whether or not you have a sound weld.

The last step is to scrape off the excess molten metal with your puddling rod when you have finished the weld. Then allow the casting to cool SLOWLY.

Holes in castings are welded much the same as cracks. Before you start to repair a hole in a casting, remember to melt or cut away the sides of the hole. This procedure takes out any pockets in the metal and allows you to get at the hole easily.

MAGNESIUM

Magnesium, lightest of the metals, is now obtained in great quantities by a war-born process which "mines" magnesium salts from the sea. As a matter of fact, a relatively small amount of sea water—something like 1 cubic mile—contains more hidden magnesium than the total recovered by man up to this time.

Alloys of magnesium are used in aircraft because of their light weight—magnesium weighs two-thirds as much as aluminum—their strength, and their excellent machinability. Machinability, as you know, means the ease with which a metal adapts itself to being shaped by cutting.

Pure magnesium, like pure aluminum, is not very strong, but by adding other metals, particularly aluminum, zinc, manganese or combinations of these metals, alloys have been developed which are very strong for their light weight.

In aircraft, magnesium alloys are beginning to be used more and more wherever a reduction in weight is important—in engine parts, landing gear, and structural airframe parts, to name a few.

You are not allowed to repair magnesium alloy parts by welding if the metal is used in a structural member. Magnesium alloys used in structural members are heat-treated and such alloys are not weldable for the same reason that heat-treated aluminum alloys are not weldable—because it is impossible to make the welded section strong enough.

A weld in sheet or plate magnesium alloy 0.05 inch or thicker, is from 60 to 90 percent as strong as the base metal, depending upon the type of alloy, its thickness and temper. You'll find that failures in the weld usually occur not in the weld zone itself, but in the nearby base metal which has been melted and then resolidified.

For use in airplanes, the magnesium alloys which are easily welded and which may also be welded to each other are AM3S, AM52S and AM–C52S, produced by the American Magnesium Company; and the corresponding Dowmetal alloys M, FS and FS–1, manufactured by the Dow Chemical Company.

Two other magnesium alloys used in aircraft—AM–57S or Dowmetal J and AM–C57S or Dowmetal J–1—can be welded only in relatively short seams. Gas welding of other wrought magnesium alloys, while possible to a certain extent, is not generally recommended. Magnesium alloys CANNOT be welded to aluminum alloys or to other metal. Welding repairs on magnesium alloy castings are not generally recommended, although cast or forged fittings may be welded into magnesium sheet structures.

CHECK FOR SIZE

Your FILLER ROD, for magnesium alloy welding, should follow the rule about having nearly the same composition as the base metal. Welding rod for magnesium welding comes in the following alloys and diameters.

AM. MAG. CO. ALLOYS (Mazlo)	DOW CHEM. CO. MAG. ALLOYS (Dowmetal)	ROD SIZE
AM3S	M	1/8, 5/32, 3/16, 1/4
AM–C52S	FS–1	1/8, 5/32, 3/16, 1/4
AM–C57S	J–1	1/8, 5/32, 3/16, 1/4
AM88S		3/16, 5/16

The approximate thicknesses of welding rods which should be used with the various thicknesses of magnesium sections are:

Welding Rod Diameter	Metal Thickness
1/8 inch	Up to 0.060 inch
5/32 inch	0.050–0.110 inch
3/16 inch	0.100–0.220 inch
1/4 inch	0.200–0.400 inch
5/16 inch	0.300 inch and more

The filler-rod comes covered with a dichromate coating which you must take off with steel wool or a wire brush before you use the rod in welding. If a welding rod is not on hand you can use a strip cut from magnesium. Be careful to remove all traces of flux from any unused portion of welding rod when you finish a weld. Otherwise it can't be used again.

Pick a welding TIP whose diameter in relation to the metal thickness checks with the following list.

Metal Thickness	Tip Diameter
below 0.050	of 0.025–0.040
0.050–0.080	0.035–0.050
0.080–0.125	0.045–0.060
0.125–0.250	0.055–0.070
0.250–0.500	0.065–0.080
Over 0.500	0.075–0.090

FLAME AND FLUX

The oxyacetylene welding flame protects the molten magnesium from oxidation because of the nonoxidizing properties of the burned gas with which the weld area is surrounded.

You can easily see why you must take special pains to keep oxygen away from molten magnesium alloys, if you remember that powdered magnesium is used for flares. As you work, bathe the weld area with the OUTER ENVELOPE of the torch

flame to keep air from reaching the molten metal. And make sure that the torch flame is adjusted to NEUTRAL so that all of the oxygen coming through the torch is consumed by the burning acetylene gas. If while working on open structures you are careful to do these two things, you should ordinarily have little trouble with oxidation.

Slant the flame at an angle of 30° to 45° to the surface of your work. The angle for THIN sheet metal should not be more than 30°, if you want to avoid burning the metal.

The FLUX for welding magnesium must be a special job. There are several good commercial fluxes on the market. Make a paste of the powdered flux by adding 0.3 quart of water to 1 pound of flux. It is best to mix up a fresh batch of flux daily rather than work with paste carried over from the day before.

In magnesium welding the flux must be COMPLETELY REMOVED after welding. Consequently, you can make only BUTT WELDS, because any other type of welded joint affords the flux too much opportunity to hide away in pockets and corners where it cannot be removed.

Lap welds and flange welds in which the flange is not melted down are thus out of the question in welding magnesium alloys. Fillet welds—welds made in a corner—should be made only in tubing. When fillet welds ARE made in tubing, you must drill holes near the welds to permit flux removal by means of rinsing.

Castings or extrusions can be welded to sheet parts if the portion of the casting or extrusion that is to be joined to the sheet part is of approximately the SAME THICKNESS as the sheet. Sections of slightly different thickness may, at times, be welded to each other, IF you are careful to preheat

the heavier section so that both edges of the seam will begin the melting process at the same time.

Recommended types of torch-welded joints are shown in figure 53.

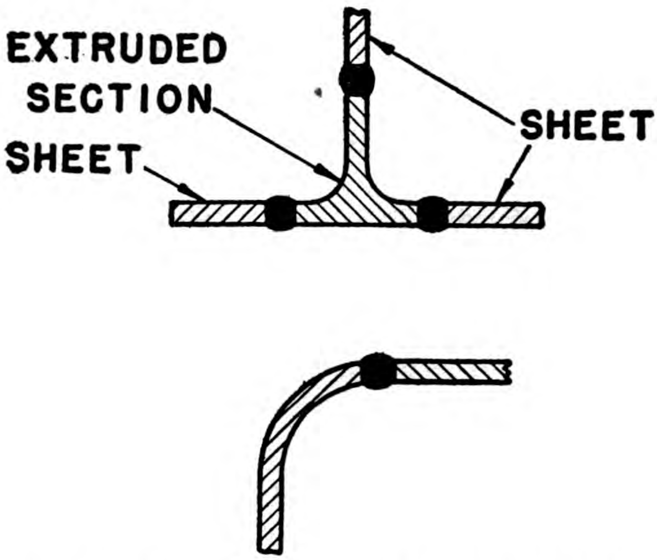


Figure 53.—Recommended types of torch-welded joints.

PREPARATION

The way you go about preparing the butt joint which you are to weld depends on the thickness of the sheet metal. Look at figure 54. Sheet magnesium alloy up to 0.051 inch in thickness should be flanged up about $\frac{3}{32}$ inch to the angle indicated in figure 54 and melted down into a butt joint.

Butt joints on metal from 0.051 to 0.125 inch in thickness are left plain—neither flanged nor beveled. Allow a space of $\frac{1}{16}$ inch between the edges of the joint.

For butt joints in metal thicker than 0.125 inch, use a cold chisel to make notches along the edges $\frac{1}{16}$ inch deep and $\frac{3}{16}$ inch apart to make penetration easier. Bevel down each edge 45° to make a 90° included angle for the vee. Do NOT bevel magnesium alloys by using a torch.

The SPACE BETWEEN THE EDGES should be 1/16 inch for metal from 0.125 to 0.250 inch in thickness. On metal 0.250 inch or thicker, leave a 1/8-inch space between the edges and build up the weld bead in more than one pass—that is, make maybe two or three trips down the length of the seam, laying down a deposit of weld metal each time. In this case, ordinary precautions to avoid oxidation of metal are not enough. The weld area should be completely enveloped in an atmosphere of carbon dioxide.

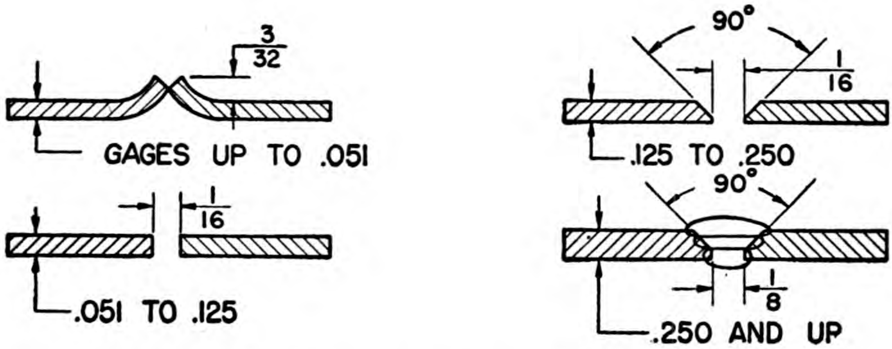


Figure 54.—Preparation of butt joints in sheet magnesium.

At this point, your joint is prepared as far as spacing, beveling and notching go. The next step is to CLEAN THE JOINT. Remove oil or grease from the weld area with naphtha, gasoline, carbon tetrachloride, or a hot alkaline cleaner. Then use a file, wire brush, or steel wool to clean and brighten the edges of the joint including the surface of the metal 3/4 inch back from the edges.

Now brush the flux paste on the under side of the parts and also coat the welding rod.

If you are repairing a CLOSED STRUCTURE and can't get at the under side of the seam to apply flux, the metal will oxidize unless you fill the part with carbon dioxide while you are in the process of making the weld.

START THE WELD by tacking the seam at intervals of ½ to 1½ inches, depending upon the type of work. If the sheet warps while you are tack-welding, it can be straightened by pounding with a wooden hammer.

When you have finished tack-welding, coat the tacks with flux and then weld completely a piece of the seam from 1 to 2 inches long at each end. You thus lessen the tendency of the metal to warp while you complete the weld. SHRINK CRACKS at the end of the seam can be eliminated by adding an excess of weld metal at that point. But use as little heat as possible to do it.

The success of your weld, except in the previously mentioned case of thick metal, depends upon your being a fast and efficient man with that torch. Do the job completely—AND WELL—in one pass. Going back over the seam to touch it up is no soap. You're asking for cracks and distortion when you use touch-up methods, and you won't be disappointed.

The way to do a good job in one pass is to keep the filler rod in the molten pool of metal. This means getting enough flux on the filler rod before you start, so that you don't have to take the rod out of the molten pool to renew the flux.

If any part of the weld begins to oxidize, it's your cue to stop. Then carefully SCRAPE OUT the oxidized portion of the weld before you continue.

Any buckling which you find it impossible to avoid through accurate lining up of the parts, closely spaced tacking, and a progressive hop-skip method of welding may be pounded out with a wooden hammer. Let the weld cool SLOWLY after it is completed.

Then, as soon as it is cool enough to handle, scrub the accessible parts of the weld lightly but *carefully* in order to REMOVE MOST OF THE FLUX. Next put the part in hot water (160°–200° F.) and soak off the large particles of flux which are sticking to any inner parts of the weld that you can't reach by scrubbing. Keep fresh water flowing constantly into the tank where the part is soaking. This prevents the accumulation of dissolved flux.

Then take the part out of the hot water, and soak it for 10 minutes in a 1 percent citric acid solution. Gas will start to bubble up from around the vicinity of the weld, thus loosening the particles of flux. If the part is made so that the gas can't escape easily, you'll have to rock or turn it frequently to prevent the formation of gas pockets where the flux might not be completely removed.

When you take the part out of the citric acid solution, drain it thoroughly and then rinse it carefully in clean cold water. This rinsing must be thorough in order to flush away the loose pieces of flux remaining inside the part.

As an alternative to the citric-acid bath you may submerge the part from 30 seconds to 2 minutes in a chrome-pickle solution. A chrome-pickle dip consists of a water solution containing—

1.5 pounds sodium or potassium dichromate.
0.2 pound magnesium sulfate.
1.5 pints concentrated nitric acid.
1 gallon of water at room temperature.

Follow this dip with a THOROUGH RINSING of the

part in cold running water and then in hot water to help along the drying process.

It is important to DRY THE PART as soon as you have finished rinsing it. A dip in clean, boiling water helps. (Do NOT use the hot water used previously.) If you have a steam table available, that is the best method.

WARNING—

Don't try to fix up a worn-out citric-acid bath by adding more acid or you will find your metal severely pitted by the action of the acid. Instead, make up a completely new bath whenever you notice that the number of gas bubbles has dropped noticeably.

To increase their strength, welds in sheets of AM3S or Dowmetal M and AM–C52S or Dowmetal FS–1 may be hammered at temperatures of 550° to 700° F after having been cleaned. Don't pound too hard or the metal will crack. Welds which join castings to sheet SHOULD NOT be hammered.

STILL MORE TESTS

The joints which the Bureau of Aeronautics requires you to weld on magnesium alloys are practically identical with those required for welding aluminum. (See fig. 51.) The types of joints are the same and the Navy demands the same results. If you're good enough to qualify on aluminum, you probably won't have any difficulty passing the tests for magnesium welding.

NICKEL ALLOYS—INCONEL AND MONEL

INCONEL is the trade name for a metal that is approximately 75 percent nickel, 12–15 percent chromium, and 9 percent iron, with small percentages of carbon, copper, manganese, and silicon.

Wrought Inconel is made up in bars, plates, sheets, strips, wires, and seamless or welded tubing. It is very resistant to corrosion and also to FATIGUE brought on by high temperature. "Fatigue" means that the metal may "get tired" and fail under vibration or shock stresses. In aircraft, you may find Inconel used in engine exhaust systems because of these qualities of corrosion and fatigue-resistance.

To weld Inconel, you have to use A FLUX. Mix it with clean water to form a paste and brush it on both the filler rod and the top and bottom of the joint. If you don't have a commercial flux, a good flux consists of 3 parts of sodium fluoride and 1 part of an equal mixture of borax and boric acid.

The FILLER ROD should be of the same composition as the base metal. Remember, too, to pick a rod of correct size for the thickness of the metal you have to work on—that is, a rod 1/16 inch in diameter for metal 1/16 inch thick, and so forth.

Welding Inconel requires a CARBURIZING TORCH FLAME (one with an excess of acetylene), rather than a neutral flame. But HOW MUCH excess acetylene? The answer is to adjust the flame until the feathery MIDDLE cone is about 1½ times as long as the brilliant inner cone. Hold your torch flame so that this feathery edge just tickles the surface of the metal. The WELDING TIP should be the same size or one size larger than that used in welding steel of the same thickness.

If you are working on thin ("light gage" is the technical term) Inconel use the FOREHAND METHOD of welding and tip your torch head at an angle of about 45° to your work.

The rule about not stirring around in the molten weld pool with the filler rod which you learned in connection with welding stainless steel, applies to Inconel, too. You're not stirring sugar into your

coffee, you're welding. Hold the end of that filler rod QUIETLY in the melting base metal if you want it to flow into the weld correctly.

JOINTS

BUTT WELDS can be made on sheet Inconel either for a closed (rigid) joint or an open joint.

With an OPEN TYPE BUTT JOINT to weld, avoid heat-distortion of the metal by spacing the edges to be joined at a SLIGHT TAPER. As you start welding from the ends which are closer together, the edges will pull together as you proceed until the gap disappears. Use this type of taper spacing on thin sheets up to 0.0625 inch in thickness. Start at the closed end with a space equal in width to the thickness of the metal and widen it toward the other end at the rate of ¼ inch for each foot of seam length.

Once you start the weld, try to finish it without interruption. If you DO have to stop, you should—upon returning to the weld—heat the weld metal to a bright red for about an inch back from where you left off. Then go on and finish. Such taper spacing refers only to open joints, because with a rigid joint you wouldn't be able to move the edges.

If you have a CLOSED OR RIGID TYPE of butt joint to weld, in Inconel, set the edges up PARALLEL leaving a space between them equal to the metal thickness. Such a set-up may mean trimming away the edges of the crack until you have a space of the right width. Then tack weld the seam at points 2 inches apart. After tacking, apply a small amount of flux to each tack. Then complete the weld, beginning at the end opposite the point from which you began tacking.

Inconel tubing is handled in the same way as sheet pieces for welding butt joints. Set up the

parts with the ends separated a distance equal to the thickness of the tube wall. Then do a little tack welding. About four tacks spaced evenly around the circumference of the tube will be enough for tubes under 2 inches in diameter. For larger tubes, use more frequent tacks.

Full penetration is just as much a virtue here as it is with any other metal, or with any other type of joint. A butt weld on sheet or tubing should show a slight bead, or thin ridge of weld metal, on the underside.

In addition, you should build up such a butt weld so that it extends above the surface of the parts joined (this is called top reinforcement) a distance about equal to the base metal thickness. Such top reinforcement should also extend out on each side far enough past the edges of the seam to make sure you have obtained good fusion of both edges.

FILLET WELDS can be made successfully on Inconel. But you have to watch out for CRACKING or PULLING OUT because Inconel is weak and brittle when it starts to harden again after being melted.

When you are fillet welding Inconel fittings NEAR THE END of a piece of sheet or tubing, one precaution you can take to get around this weakness of Inconel is to heat the metal to a bright red all the way out to the end before you begin the weld. Then when you get through welding go back and reheat the same part to reduce the stresses and prevent buckling and cracking.

Use jigs, wherever you can, to hold the pieces in line. As a matter of fact, it is smart to use jigs no matter what type of joint you have to weld.

Clamp the metal in the jig tight enough to hold the edges so that they line up right. You CAN overdo the clamping business though. You don't

necessarily break the metal by fastening the clamps too tightly, but you do restrain the normal contraction of the metal as it cools after being welded. This restraint may result in cracking near the weld.

A copper backing plate should be used to hold the molten metal at the bottom, or root, of your weld. It should be grooved to a depth of $\frac{1}{32}$ inch to allow full penetration so that a slight bead can be seen on the under side of the weld when you have finished.

Plenty of fresh air is a good thing to have around when you are welding Inconel because the fumes from the melting flux are poisonous—NOT recommended for breathing purposes.

MONEL METAL

MONEL metal is a trade name for a nickel alloy which contains 60 to 70 percent nickel, 23 to 30 percent copper plus small amounts of carbon, iron, manganese, and silicon.

Monel metal is manufactured in wrought bar, sheet, tube and wire forms as well as in castings for special purposes. It is strong, tough, ductile, and highly resistant to corrosion from many acids and alkalies.

Practically all of the welding processes can be used on Monel. A FLUX is necessary to protect the hot metal from the oxygen in the air. The flux also dissolves any oxides present in the metal and floats them out so that you have a good, nonporous weld. Mix the flux with hot water to form a thin paste and paint it on the filler rod and edges of the Monel. In addition to the commercial fluxes, borax, boric acid, or a mixture of the two in alcohol is all right.

The FILLER ROD must have the same composition

as the Monel. If you don't have a conventional welding rod of the right type handy, a strip cut from a sheet of Monel will do.

Hold the torch at a 45° angle to the surface of your work and use the BACKHAND method so that the flame can envelop the molten weld metal and exclude the oxygen from the air.

Sheet Monel metal stock should be welded in a JIG in order to keep the edges alined and reduce any buckling.

Use a BACKING PLATE under the weld and have a small groove to allow full penetration, the same way you do in welding Inconel.

When you have a BUTT JOINT to make in welding thin Monel metal sheet—up to 0.0625 inch in thickness—turn up flanges about 1/16 inch high at an 80° angle. The edges of the flanges thus will come together at the top at a 20° angle and the flanges themselves will not be quite parallel—an anti-warping trick. Before welding such flanged butt joints of Monel, apply a thin flux to the flanges and tack-weld the seam every 2 to 4 inches in order to hold the seam at an even height. Now that the weld is prepared, the next step is to melt down the flanges as rapidly as you can to avoid burning the metal.

Butt joints on sheets heavier than 1/16 inch should be beveled. The edges should be separated about 1/32 inch at the end where the weld is to start and the space should gradually widen about 3/8 inch for each foot of seam length. When you clamp the pieces in a jig, do it lightly enough so that the contraction forces set up in the base metal by heating will not be restrained.

In working on thick pieces, there are two things to remember. One is to BUILD UP THE BEAD TO ITS FULL HEIGHT as you go along. Welds built up in layers are weak because each layer will be

separated by an oxide coating from the next layer. The second point to keep in mind is to build up the weld WELL ABOVE the surface of the base metal, thus allowing a margin of weld metal which may contain any oxide film and impurities which have been floated to the surface. The impurities, therefore, will be on top and can be ground or machined off, leaving a sound, clean weld.

MORE PRECAUTIONS FOR CASTINGS

There are a couple of extra steps you must take if your piece is a Monel CASTING. The first step is to bevel and line up the part, if it is broken. Bevel off all sand, oxide, or other foreign matter and bevel down the edges of the break at a 45° angle to the full depth. A strip ½ inch wide along the surface of the casting at the point of the break should be ground until bright metal shows.

The second step is to preheat the casting before you start the weld to prevent distortion and also to keep more breaks from cropping up because of expansion and contraction.

You can't just wave a torch around over such a casting and expect it to be preheated. You should put the casting in a furnace and bring it SLOWLY AND EVENLY to a dull red heat.

When your part reaches this dull red temperature, take it out and cover it with asbestos sheeting. This sheeting should have an opening in it just large enough to let you work on the break without exposing all of the casting to the cooling effect of the air. Then, when you finish the weld, completely cover the piece up again and put it back in the furnace to cool off slowly as the furnace is cooling.

TESTS AGAIN

Be sure you can weld very thin and comparatively heavy sheet Monel and Inconel metal. Before you can become a certified welder you have to pass a test on butt and T fillet welds in both thin and heavy Monel and Inconel like those for heat and corrosion-resisting steels.

You may also expect to be given several aircraft parts made of these alloys to weld.

The joints will be inspected for penetration and fusion and subjected to a bend test in the same manner as were those on stainless steel.

MELTING POINTS

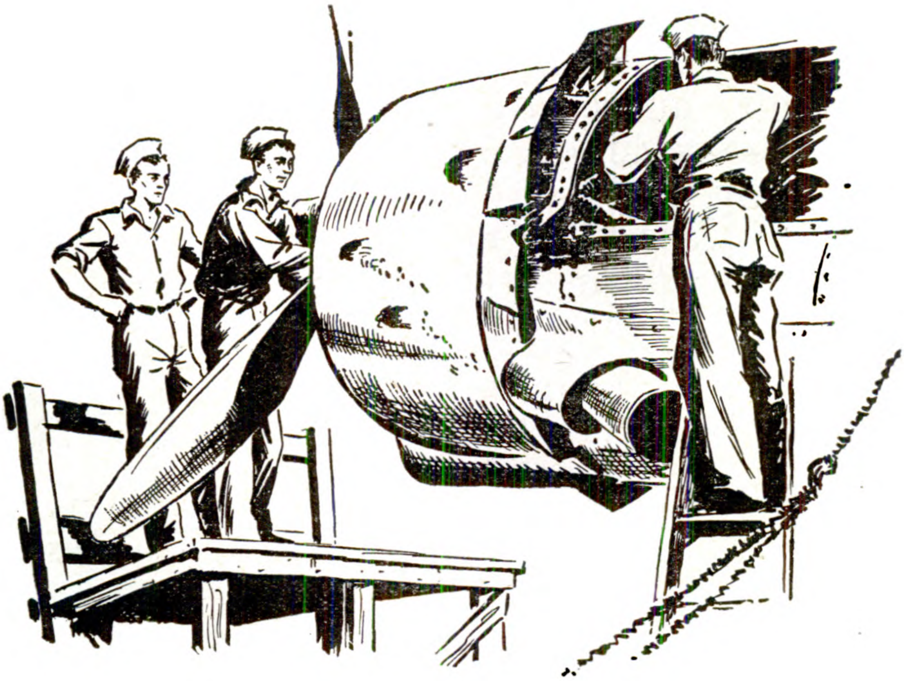
One of the most important characteristics of metals from YOUR standpoint is the melting points of the various aircraft metals. You apply this knowledge, for example, in deciding whether to weld or braze two dissimilar metals.

If there is a wide spread between the melting points of the two metals, then you know that it would be hard to get them both to fuse. One might still be below its melting point when the other is far above its melting point and probably burned. If a brazed joint would serve the purpose, it would be preferable in such a case because in brazing the two metals do not need to be melted.

Here is a list of the melting points of some of the metals you may have to handle in aircraft work.

Metal	Melting Point ° *F.*
Aluminum, cast, 8 percent copper	1,175
Aluminum, pure	1,218
Aluminum, 5 percent silicon	1,117
Bismuth	520
Brass, commercial High	1,660

Metal	Melting Point ° F.
Bronze, Tobin	1,625
Bronze, Manganese	1,598
Chromium	2,740
Copper, deoxidized	1,981
Copper Electrolytic	1,981
Iron, cast	2,300
Iron, malleable	2,300
Iron, wrought	2,900
Lead	620
Molybdenum	4,532
Monel metal	2,400
Nickel	2,646
Silver	1,762
Steel, hard (0.40–0.70 percent carbon)	2,500
Steel, low carbon (less than 0.15 percent carbon)	2,700
Steel, medium (0.15–0.40 percent carbon)	2,600
Steel, manganese	2,450
Steel, nickel, 3½ percent	2,600
Steel, cast	2,600
Stainless steel (18 percent chromium, 8 percent nickel)	2,550
Stainless steel (18–8 low carbon)	2,640
Tin	450
Vanadium	3,182
Zinc, cast or rolled	786



CHAPTER 5

TUBING REPAIR

CHROME-MOLY

Present-day airplanes don't use as much structural steel tubing as they formerly did because of the trend to monocoque and other stressed-skin structures. The skin of the airplane, rather than inner structures of steel tubing, now carries a large part of the loads and stresses during flight.

There is still, however, a certain amount of steel tubing used in airplanes fuselages and engine mounts. It is made of a steel alloy called chrome-molybdenum or "chrome-moly" (1 percent chromium, 8¼ percent molybdenum).

Chrome-moly is easy to weld, has a high initial strength, and is highly shock-resistant. Code name for the most common kind of chrome-moly is S. A. E. No. X–4130. It comes in both sheet and tubing forms.

One of the advantages of welded steel construc-

tion in airplanes is the ease with which repairs can be made. Steel tubing, or sheet stock, used for repair can be either 1025, X–4130, or 8630. These repairs can often be made in the field, since the only equipment necessary is a short section of steel to replace the bent or broken member, some welding apparatus—and someone who knows how to use the apparatus. And that is where YOU come in.

WATCH THESE

The following suggestions and precautions will help you when you weld chrome-moly tubing and fittings.

A SOFT, NEUTRAL flame should be used. The outer envelope of the flame should not be more than one and one-half times the length of the inner cone and not more than 1/8 inch long. The size of the welding tip you choose is governed, of course, by the thickness of the metal. Within these limits the best choice is a tip large enough to permit fairly rapid welding while at the same time small enough to avoid overheating and burning the metal. An oversize tip speeds up the work but makes it hard to avoid overheating. You want NO PART of burned metal because it weakens your joint so that it cracks as it contracts in cooling. For the same reason, avoid rewelding. You again run the danger of overheating the metal. You don't want to make mistakes which might result in structural failure and possible disaster. Small mistakes in aircraft repair welding can gather extremely grave consequences.

Keep the flame pointed in the direction of welding in order to preheat the metal.

Use a mild-steel (a low carbon) FILLER ROD for welding chrome-moly steel. Although attempts have been made to use a rod of alloy steel, the

authorities say that these rods don't offer enough advantages to offset the difficulty in using them. A mild-steel rod flows smoothly and makes a sound, uniform weld. FLUX IS NOT NEEDED.

Welds in aircraft tubing must NOT be dressed (filed or smoothed down) unless further welding is to be done on the dressed section. If you are welding thin tubing—less than 0.040 inch—your weld should be not wider than ¼ inch.

Chrome-moly is strong and tough when cool, but it is as weak as a day-old kitten at high temperatures. Although such weakness is a characteristic of all steels, it is even more apparent with a high-strength alloy steel like chrome-moly than with ordinary steels. Because of this weakness, the metal may crack if it is put under even a comparatively slight stress while it is still white hot. So the rule with white-hot chrome-moly is—HANDLE WITH CARE.

This means taking a couple of specific PRECAUTIONS. DON'T use welding jigs that might hamper expansion and contraction of welded members. And BE ESPECIALLY CAREFUL to avoid overheating the metal when you are welding at or near an edge. Edges heat up quickly and before you know it you may have cracked the metal. A good way to go easy on edges is to draw your welding flame away slightly when you find you're in the vicinity of one.

> CAUTION.—After you make a weld on steel tubing, DON'T FILE OR SMOOTH it and don't add any solder or filler to improve its appearance. You're not interested in "pretty" welds—only in strong welds.

Another precaution you must take is to make sure that you adequately replace any corrosion-control materials which you may have removed

while making a weld. Corrosion, as you know, is a constant enemy of aircraft operating under combat conditions—or under any conditions.

After a section of steel tubing has been repaired by welding, you must first sandblast all outside surfaces and immediately apply a shop coat of zinc chromate primer. Handle the sandblasted surfaces AS LITTLE AS POSSIBLE before applying the primer. In the case of seaplanes, the surfaces should be sandblasted, then immediately metal sprayed, followed by a protective coating of zinc primer.

BEFORE YOU WELD

First clean the parts thoroughly by taking off all grease, paint, or other foreign substance from the section to be repaired. Follow the general instructions given at the beginning of Chapter 2.

Those three familiar reactions—expansion, contraction, and shrinkage—which take place to some degree in all metals when heat is applied are, of course, still present when you weld chrome-moly aircraft tubing. It is also important to prevent too much loss of metal thickness from excessive scaling (formation of iron oxide).

CRACKING can be prevented by cutting down the strain caused either by the weight of the parts or by the restriction of normal expansion and contraction. For this reason, in welding chrome-moly tube assemblies, it is a good idea to completely weld one end of the web member to the flange member of a truss and to allow it to cool before you start to weld the opposite end of the web member.

In the same way joints of an assembly in which SEVERAL members terminate should be welded first and should be allowed to cool before you make any attempt to weld the opposite ends. Assuming

that these members are connected to similar joints at their opposite ends, you should also use heavy clamps, chill plates, or wet asbestos on the members near the weld. This method helps to prevent expansion caused by heat travel. As you can readily see, welding a number of joints that terminate in such an assembly naturally takes more time and requires more heat than merely welding a single member into a joint. Consequently, there is a greater amount of expansion.

In the welding of fittings, you can checkmate shrinkage strains and the consequent danger of cracking by starting your weld at the FIXED END of the seam and working TOWARD THE OPEN END.

It is also a good idea to relieve the stresses of alloy steel parts AFTER welding by a process known as DRAWING OFF. This means heating the entire part uniformly to a temperature between 1,150° and 1,200° F., and then permitting it to cool slowly. If you don't have the equipment available for heating the whole piece, you can get the same effect by using your torch to heat the part for a radius of several inches around the weld area.

Say you have a joint to be secured by BOTH riveting and welding. What you do is to line up the rivet holes and complete all the welding before the rivets are driven. If you wait until after the rivets are driven to make your weld, the expansion and contraction forces develop a shearing stress on the rivets and tend to stretch, or elongate, the rivet holes.

In welding tubing assemblies WARPING can be controlled by the use of enough clamps and the right kind of jigs. Progressive welding—that is, the hop-skip technique—throughout the piece also helps cut down distortion. Another way to prevent warping is to rig up a device for directing

a torch flame on the opposite side of the piece. This process heats the part while you weld it and thus reduces strains in the part.

MINOR OPERATIONS

Most repairs on aircraft tubing require a major surgical operation—the cutting out and welding in of a partial replacement tube, or replacement of a whole new section of tubing. Some, however, are comparatively minor, like when a doctor gives you a local anaesthetic and pulls out your tonsils.

An example of a minor operation in repairing aircraft tubing is straightening a piece of fuselage tubing that has become slightly BUCKLED or BENT. Such repair is a comparatively simple matter. As a matter of fact, if the part is made of unheat-treated metal, it will normally be stronger after having been straightened. This strength is due to the cold-working the metal undergoes as you straighten it.

You need a steel screw **C** clamp, three blocks of hardwood, and a piece of channel iron of the same length as the bow, or bend, in the tube. Cut the wood blocks to fit the shape of the tube and line the grooves with leather or canvas. Place one of the grooved blocks at either end of the bent section and apply the channel iron so that it spans the bent area and backs up the two blocks as in figure 55.

Apply the third block on the opposite side of the tube at the point where the bend is greatest. Slip one end of your **C** clamp over the channel iron beam and tighten the clamp down on the block at the center of the bend.

Tighten the clamp until the tube is bent slightly in the OPPOSITE DIRECTION. Now remove the clamp and

the blocks. Check the alinement of the tube by placing an accurate straightedge on both the side and the top of the tube. If the straightedge check tells you that there is still a slight bow in the tube, put the blocks and clamp back on again and repeat the process until the tube lines up with the straightedge in both planes.

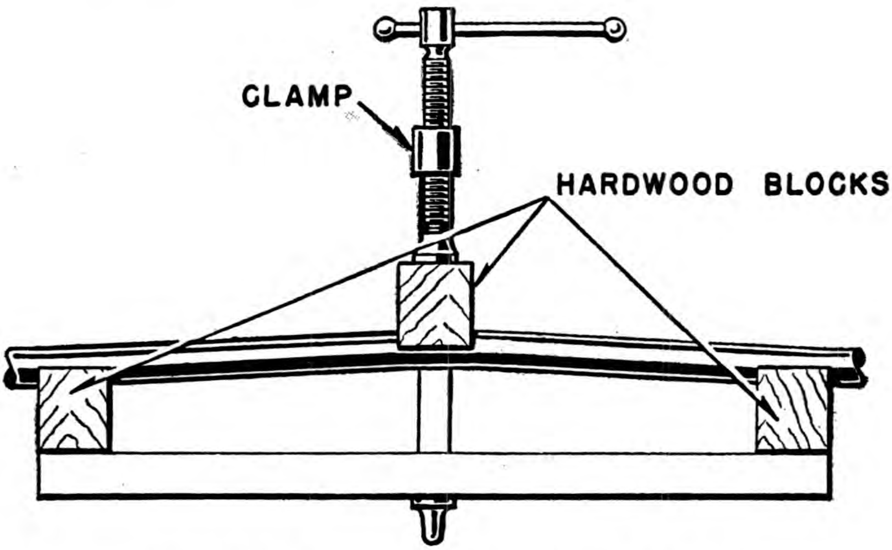


Figure 55.—Straightening a bent piece of tubing.

If cracks appear at the point where the maximum bend was corrected, you will have to drill a hole at the ends of the crack and weld a split steel sleeve over the crack. (More about split sleeves later.) In every case where a bent tube is straightened, you must carefully test all nearby welded joints for cracks. When cracks appear, you must repair them.

Another small local failure in tubing is one in which a piece has become slightly OVAL-SHAPED OR OUT-OF-ROUND. To fix such a failure, drill a steel block to the diameter of the tube. (See fig. 56.) Then saw the block in half, lengthwise of the hole and separate the two sections of the block. Next place these two sections on the af-

fected area of the tube. Slip a heavy clamp over the blocks, tighten it and apply pressure to the area until the tube assumes its normal, circular shape. The affected tubing may be heated to a DULL red as an aid in re-forming it. If the dented or out-of-round area is longer than the length of the form blocks, you will have to reapply the blocks and clamp until the entire length of the out-of-round area is restored to its normal shape.

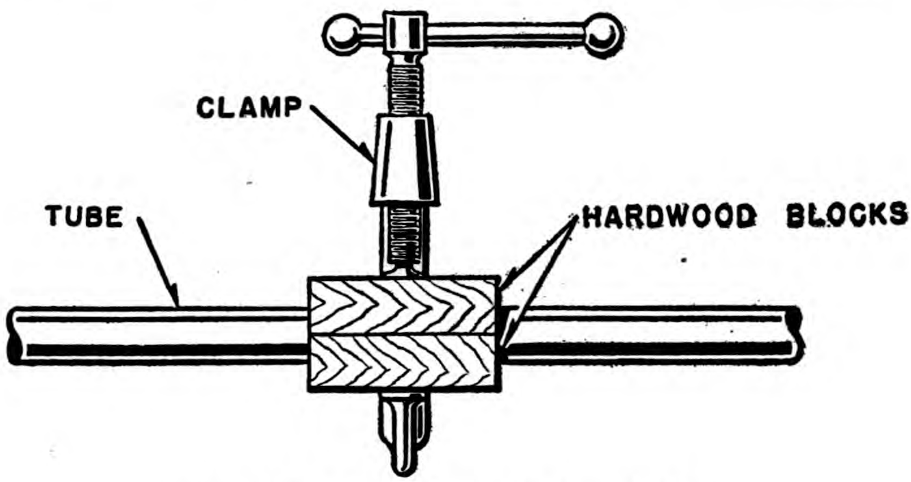


Figure 56.—Re-forming out-of-round tubes.

Suppose you have a MINOR SMOOTH DENT in some tubing, but the piece is not out-of-round for any considerable length. An easy way to take out the dent is to PUSH it out by air pressure. To accomplish this repair, remove one of the self-tapping screws provided at the ends of the main steel tubes and apply an air pressure of 75 pounds or more per square inch to the inside of the steel tubing. With your torch, heat the dented area evenly to a dull red until the internal air pressure forces out the dent and restores the original shape of the tube.

If the combined internal air pressure and heat are not enough to remove the dent, tack weld a welding rod to the center of the dent. Then pull

on the rod while you heat the area. After the dent is removed, disconnect the rod, allow the area to cool and then release the internal air pressure. FINALLY, replace the self-tapping screw which you had removed.

What do you do if you suspect a piece of tubing of having SMALL CRACKS at a joint? You test the suspected area by wiping off the oil and then applying a coat of whiting. The crack, if any, usually gives away its presence by the appearance of oil on the whiting.

When you have located the crack, remove all finish from the area with steel wool or a wire brush. If the crack is located in an original weld bead, carefully chip, file, or grind out the existing weld bead, then, reweld over the crack along the original weld line. Be particularly careful not to take away any of the existing tube or reinforcing material when you grind off the weld bead.

If the small crack shows up near a cluster joint but not actually on the weld bead, remove the finish and then drill a No. 40 (0.098) hole at each end to prevent the crack from growing. Now weld an overlapping piece of metal in place over the area. When you have completed the job, apply a coat of zinc chromate primer to the area from which you removed the finish. Finally, apply finish coats to match the neighboring surfaces.

If previous attempts to straighten the tube have caused it to be SHARPLY DENTED OR CRACKED, it can either be reinforced or the damaged part can be cut out and replaced. If the damage is not too serious, you may decide to reinforce the part by means of a SPLIT SLEEVE and leave it in the structure. In that event, your reinforcing material

should be a piece of steel tubing having an inside diameter equal to the outside diameter of the damaged tubing. The two tubings should have the same wall thicknesses.

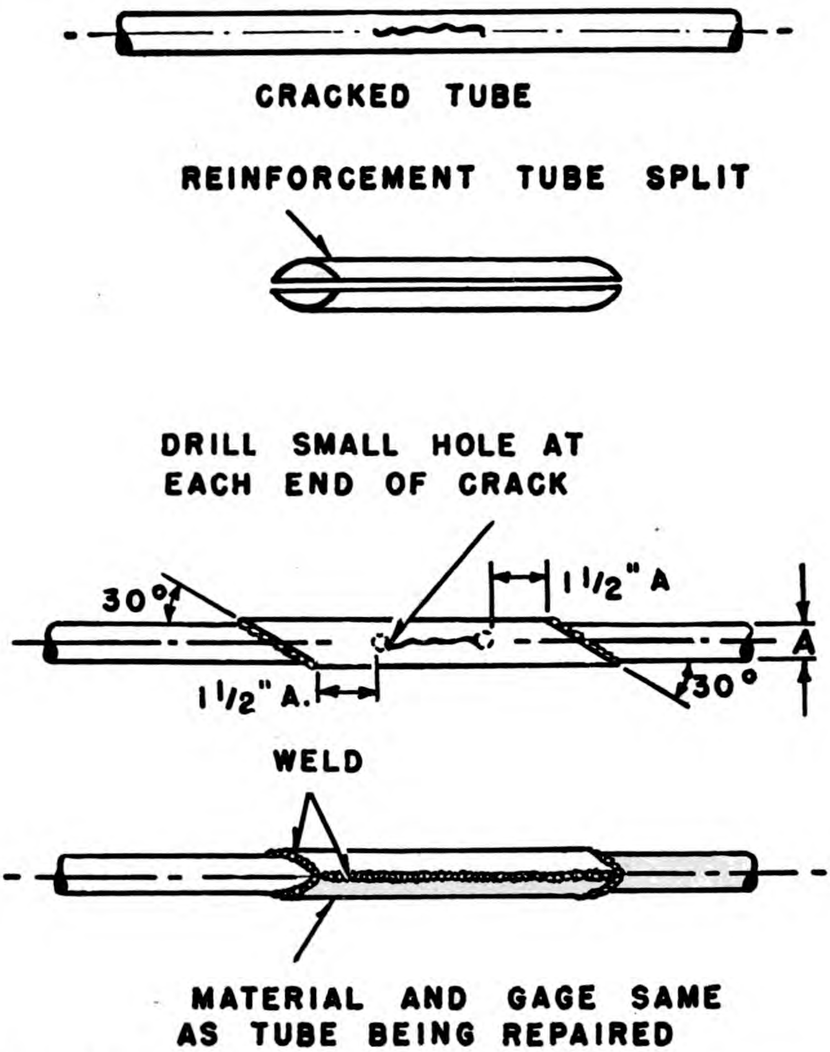


Figure 57.—Cracked-tube reinforcement by means of a split sleeve.

Cut both ends of the reinforcing sleeve diagonally at about a 30° angle. The sleeve should be long enough to extend a distance of 1¼ tube-diameters past each end of the crack as in figure 57. Cut the reinforcing sleeve in half lengthwise and separate the half sections. Remove the finish from the surface of the affected area with steel

wool for 3 inches on each side of the damage. Now, clamp the two sleeve sections over the damaged area of the original tubing. Weld the two halves of the reinforcing sleeve together and then weld both ends of the sleeve to the damaged tubing. Last, refinish the surface of the joint according to the instructions given earlier on anti-corrosion precautions.

The usefulness of PATCHING is not limited entirely to reinforcing the seat of your pants. You can also repair SHARP DENTS AT A STEEL TUBE CLUSTER JOINT when it is not necessary to remove the entire joint. This patching is done by welding a specially formed steel tube patch over both the dented area and the adjacent tubes in the cluster as in figure 58.

Your patch should be made of X4130 chrome-moly sheet steel with a thickness equal to or thicker than the wall of the damaged tube. Trim the patch so that it will extend past the dent in both directions a minimum of two times the diameter of the tubing. Lay out the patch so that it has fingers as wide as the brace members. These fingers should extend up over the brace members a distance of 1½ times the tube diameter. Round the ends of the fingers and the corners of the patch so that the heat will be well-distributed during welding. Next with steel wool, rub off all the existing finish from the damaged cluster joint.

Clamp the patch into position and tack-weld it in several places where its edges touch the tubing. Next, heat it and use light hammer blows to make it fit the contour of the tubing. Avoid unnecessary heating during the pounding process. But, on the other hand, use enough heat to enable you to fit the patch to the tubing with a gap of no more than $1/16$ inch between tubing and patch.

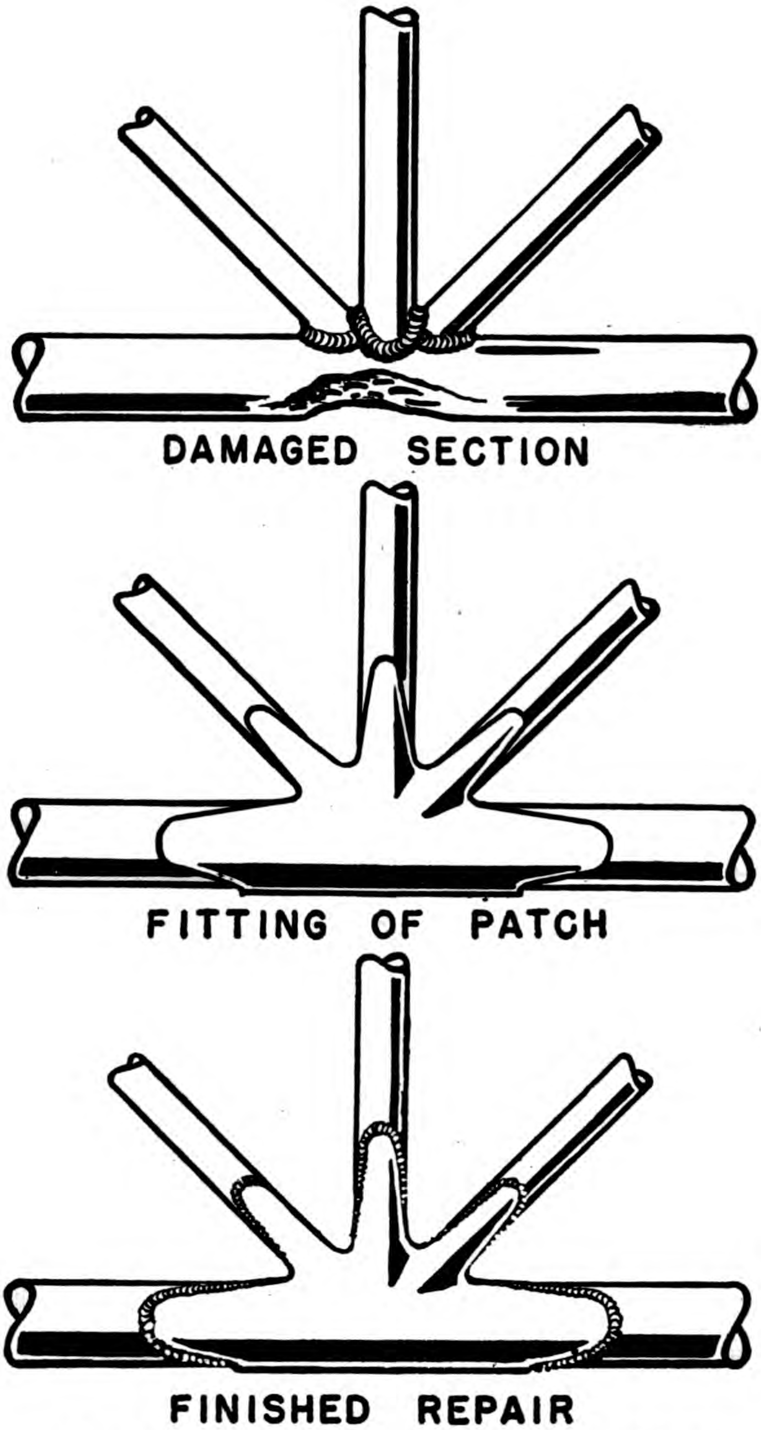


Figure 58.—Repairing sharp dents at a cluster joint.

Now weld around the edges of the patch so that it is fused to all the tubes in the joint. To refinish the surface around the joint, follow the instructions given earlier on anticorrosion precautions.

Unless the damage to members of a steel tube structure is comparatively slight, you will usually find it is a better idea to take out the injured part and weld in either a partial replacement tube or an entirely new piece of tubing.

Tubes and section are ALWAYS cut out with a hacksaw—NEVER by oxyacetylene flame cutting. The number of tubes you decide to remove and the way you do it, depends upon WHERE the damage is located and HOW GREAT it is. Tubes inserted as replacement are joined at their ends by means of a SPLICE.

Splicing of partial tube replacements may be done by using a replacement tube of the same diameter plus either internal or external reinforcing sleeves. Or, it may be done by using an EXTERNAL REPLACEMENT TUBE of the next larger diameter. Such a replacement tube is spliced to the stub ends of the original tubing.

Each type of splice has its particular advantage and use, even though the methods involved in making them are essentially the same. If the original damaged tube includes castings or fittings that have been made to fit the tube then, of course, your spliced replacement tube must be of the same diameter as the original tubing. Therefore, you will have to use either INTERNAL OR EXTERNAL REINFORCING SLEEVES under or over the splices. If no fittings are attached to the original tubing, you can usually use an external replacement tube.

Two types of splice welds are permitted in the repair of aircraft tubing. One is the DIAGONAL weld. The other is the FISHMOUTH weld. NEVER make a splice by butt welding. The fishmouth type is always the best because it is stronger. Its strength lies in its resistance to bending stresses. In the fishmouth weld there is no single straight

line of weld through the structure. Therefore, a straight-line break cannot occur if the part is subjected to shock or vibration. Sometimes, however, the damage and its location will be such that you must use a diagonal weld.

You CANNOT make a cut for splicing purposes in the MIDDLE THIRD (see figure 59A) of a section of tubing because of the high bending stresses which aircraft tubing must withstand.

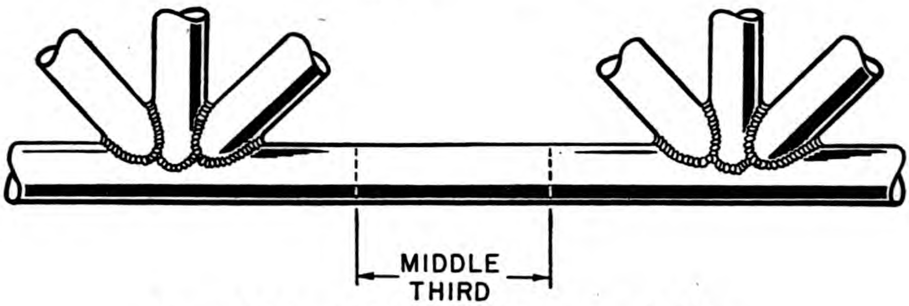


Figure 59A.—Middle third of a section of tubing.

And only ONE partial replacement tube can be inserted in ANY ONE SECTION of a structural member. If more than one tube in a joint is damaged you must remove the entire joint and put in a new, preassembled and welded joint of the right design.

If a WEB MEMBER is damaged AT A JOINT so that it is impossible to retain at that point a stub long enough to permit the splicing on of replacement tubing, you must put in an entirely new web member.

If a continuous longeron is damaged AT A JOINT, you must be sure that the replacement tube splices on either side of the joint are far enough from the joint to avoid weakening the weld. If too close, they increase the basic weakness of the weld. First cut loose the web member at the affected joint and remove the damaged section of tubing. Then splice the replacement tubing to the stub ends of the original section of longeron. And finally, weld the web member to the new section of longeron tubing.

Use wooden braces to keep the tubes in alinement as you make the repair. When you replace bent or damaged tubes with new tubes, it is a good idea to check the original alinement of the corresponding tubes on an undamaged airplane.

INNER REINFORCEMENT

Look at figure 59B. Here you have a PARTIAL REPLACEMENT TUBE spliced to the original tubing BY MEANS OF INNER REINFORCING SLEEVES—a method

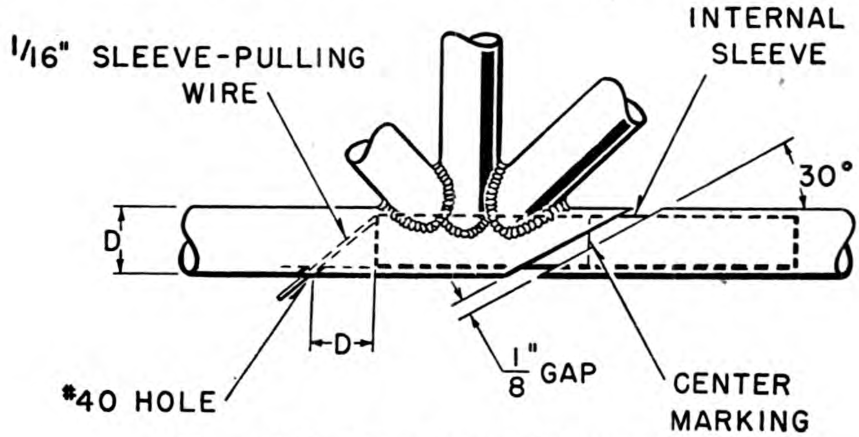


Figure 59B.—Inner-sleeve reinforcement.

that rates high in the Navy. There is a minimum of welding to be done, and consequently there is little chance of weakening or distorting the tubing. This method has the advantage of giving a smooth outer surface to the repaired section.

The first thing you do is make diagonal cuts in the affected tubing so that you can remove the damaged portion. Be sure that you locate your cuts AWAY FROM THE MIDDLE THIRD of the affected tube section. When the part has been removed, file off the burr, or roughness, from the edges of the cuts. Now pick a replacement tube that matches the damaged original tubing in both diameter and wall thickness. Cut from it a length which is $\frac{1}{4}$ inch less than that of the removed section by means of similar diagonal cuts on the ends. You will now have a $\frac{1}{8}$-inch

gap between each end of the replacement tubing and the original tubing.

Now cut a couple of reinforcing sleeves. Saw straight across (not diagonally) through the tubing. For this purpose select tubing of the same wall thickness as the original tubing and with an OUTSIDE diameter equal to the INSIDE diameter of the original tubing. The sleeves should make a snug fit inside the original tubing. The clearance between sleeve and tubing should be no more than $\frac{1}{64}$ inch. These inner sleeves should be long enough so that either end of a sleeve is not less than $1\frac{1}{4}$ tube diameters from the diagonal cuts in the original tubing and the replacement tube, as in figure 61.

Now you are ready to get going on the actual job of splicing. The success of the splicing process depends on following a logical, step-by-step procedure.

Set up a brace arrangement to support the structure while you weld. In figure 60 you can see how the brace takes the place of the damaged tubing in holding the vertical members in alinement while you work.

Dip the replacement tube and inner sleeves into hot (about 165° F.) Paralketone. It helps prevent corrosion. Wipe off the Paralketone from the outside of the replacement tubing and sleeves.

Now make a small mark on the outside of each original tube stub end, halfway along the diagonal cut, as in figure 61.

Next measure off a distance $2\frac{1}{4}$ tube diameters long from the nearest end of each diagonal cut on the original tubing. Center punch the tube at these points and start drilling holes—No. 40 size—with your drill held at a 90° angle to the surface of the tubing.

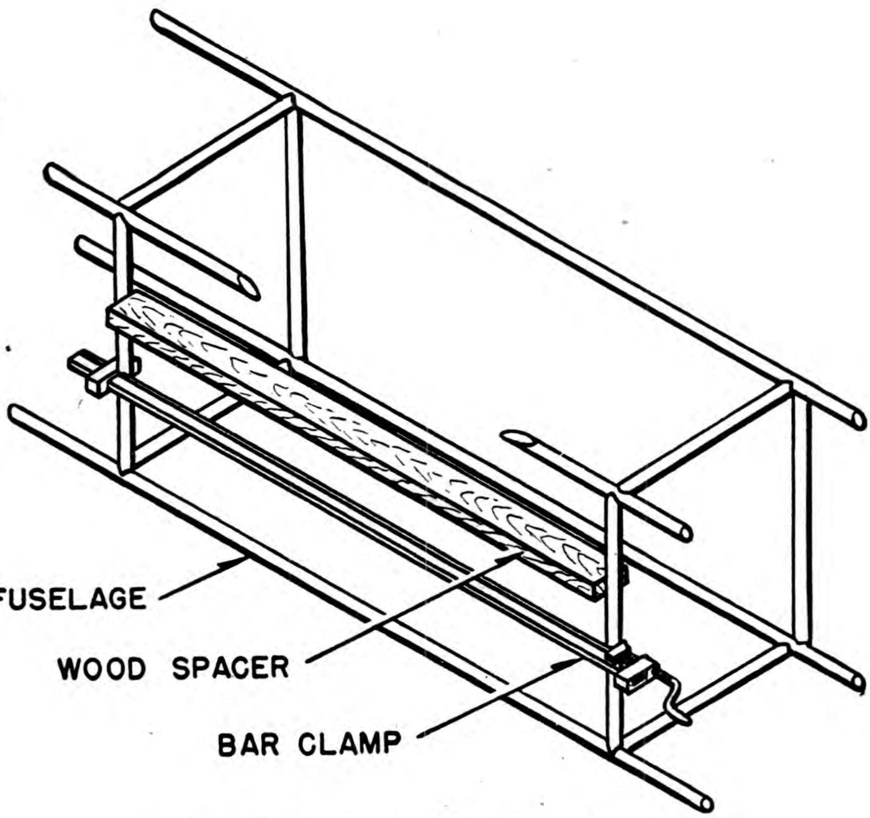


Figure 60.—Brace for alining members.

After you have the hole started so that the drill will not jump out, slant the drill TOWARD the cut and continue at a 30° angle. File off the burr from the edges of the holes with a round, needle-point file.

This step is easy. Simply pick up a length of 1/16 inch welding or brazing wire, stick one end through the hole you have just drilled and push it out the diagonally cut open end of the original tubing. Now do the same thing at the other stub end. You use these wires to draw the sleeves into the tubing.

Next weld the end of each wire which sticks out the open end of the tubing to the INSIDE of one of the inner sleeves as in figure 61. To help in drawing the sleeve into the tube, bevel the ends of the sleeves to which the wires are welded.

Make a narrow mark around the centers of the reinforcing sleeves either with thin paint, metal dye, or emery paper.

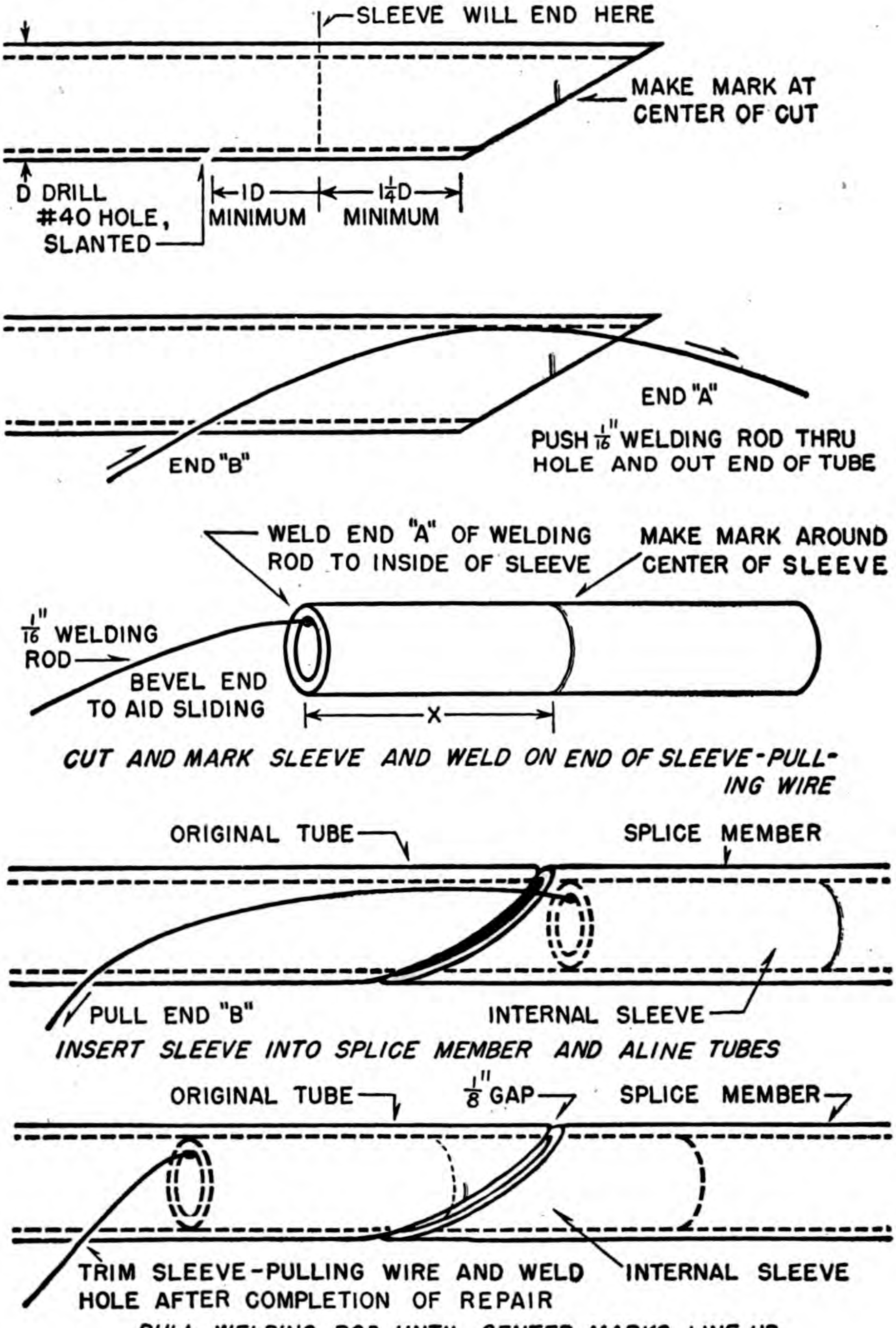


Figure 61.—How to draw inner sleeves into tubing.

At this juncture, you push the inner sleeves into the replacement tube so that the point

where the wire is welded to the sleeve is 180° from the drilled hole. If the drilled hole is at the bottom of the tubing, the inner sleeves are placed so that the point at which the wire is welded is at the top. If the inner sleeve fits too tightly in the replacement tube, chill the sleeve with dry ice or in cold water. If the sleeve still sticks, polish it with emery cloth.

Now line up the stub ends of the original tube with the replacement tube.

Next, start pulling the end of the wire which sticks out of your drilled hole. Pull the sleeve along until the center mark on the sleeve is directly in line with the center mark on the diagonal cut. When you have these two marks lined up, the sleeve is centered beneath the joint, as in figure 61. Repeat this process for the other sleeve at the opposite end of the replacement tube.

Last of all, bend the pulling wire over the edge of the hole so as to hold the sleeve in position and weld the inner sleeve to the original tube stub and replacement tube at one end. This fills the ⅛-inch gap between replacement tube and original tube at one end. See figure 61. Be sure that you form a weld bead OVER the gap. After the joint is welded, snip off the pulling wire flush with the surface of the tube and weld over the drilled hole.

Take time out to let this weld cool. Then adjust the brace to provide for contraction and shrinkage. After you have adjusted the brace, pull the sleeve into position and tack-weld the gap at the other end of the replacement tube. This will hold the joint in alinement. Next REMOVE the brace so that there will not be any restraint of the contraction

forces at this joint. And, finally, complete the weld around the gap that you have previously tackwelded.

There! The replacement tube should now be welded into place—neatly reinforced with inner sleeves at the joints.

This same general method can be used for any of the other splice methods which follow. Except, of course, that you don't need to fool around with a sleeve-pulling wire when you use external reinforcing sleeves or where you dispense with the sleeves and use simply a replacement tube of larger diameter.

OUTSIDE SLEEVE REINFORCEMENT

A partial replacement tube of the same diameter as the original, reinforced by OUTSIDE sleeves is another way to repair tubing. Since this method requires the greatest amount of welding of any of the three methods mentioned, there is more danger of distortion from the heat of welding. Therefore, it is the least desirable of the three methods. However, there may be times when the damage is so located that you can use neither the inner sleeve type of splice nor the larger diameter replacement tube. In such cases, the outer sleeve type of splice like that in figure 62, is your choice by necessity.

YOU PROCEED AS FOLLOWS—

First, cut out the damaged section of tubing, sawing straight across, not diagonally, through the tubing. Be sure you locate the cuts away from the middle third of the affected section. Then cut a section of replacement tubing which matches the original tubing in diameter, wall thickness, and length. There should be a gap of not more than $\frac{1}{32}$ inch between the ends of the

replacement tubing and the stub ends of the original tubing. For the outer reinforcing sleeves select a length of tubing with an inside diameter equal to the outside diameter of the original tubing. (There should be clearance between sleeve and tubing of no more than 1/64 inch.) Saw out the sleeves with either diagonal or fishmouth ends—fishmouth ends are preferable. Make the sleeves long enough so that their nearest ends are at least 1¼ tube diameters from the ends of the diagonal cuts in the original tubing.

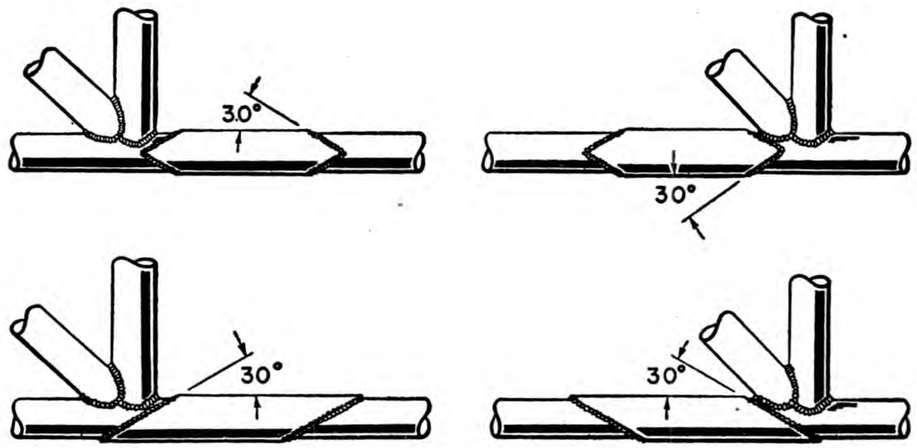


Figure 62.—Outside sleeve reinforcement.

Now file off the burr from the edges of both sleeves and reinforcing tubing and then dip them in a bath of hot (165° F.) Paralketone. After wiping it off the tube and sleeves, slip the two sleeves over the replacement tubing. Line up the replacement tubing with the stub ends of the original tubing and push the sleeves along until they are centered over each joint. Rotate them to suit the space and to provide the greatest reinforcement.

Tack weld the two sleeves to the replacement tube in two places. Now weld both ends of ONE sleeve completely to the replacement tube and

original tube. Let this weld cool to prevent undue warping before you weld around both ends of the OTHER sleeve.

LARGER DIAMETER REPLACEMENT TUBE

Dispensing with reinforcing sleeves and using a larger diameter replacement tube takes the least amount of cutting and welding. Consequently, it is desirable from the point of view of controlling the distortion caused by the heat of the welding flame. You CAN'T use it, however, WHEN you have a tube that is damaged too close to a cluster joint because there will not be a sufficiently long stub end.

BUT how about carrying the splice PAST the joint into the next section of tubing? Bad idea! That would mean adding unnecessary weight to the structure.

Also, tubing of larger diameter can't be used if brackets are mounted on the original tubing. In this case, the replacement tubing must be of the same diameter as the original.

When you use this type of splice, cut out the damaged tubing so that you have at one end a SHORT STUB with a length of at least 2½ tube diameters, and at the other end you have a LONG STUB with a length of at least 4½ tube diameters. The cuts must be outside the middle third, as in figure 63. Cut the replacement tube from a spare length of steel tubing having an inside diameter about equal to the outside diameter of the original tubing. Again, the clearance between the two should be no more than $1/64$ inch. Cut the ends of the replacement tube either diagonally or fishmouth style, preferably fishmouth. The replacement tube should be long enough so that

each end extends at least $1\frac{1}{4}$ tube diameters past the ends of the original tube.

File the burr from the edges of the replacement tube and the original tube stubs. If you have cut the ends of the replacement tube fishmouth style, file out the sharp inner angle of the fishmouth. Next, dip the replacement tube in hot (165° F.) Paralketone, and then wipe it from the outside of the tube.

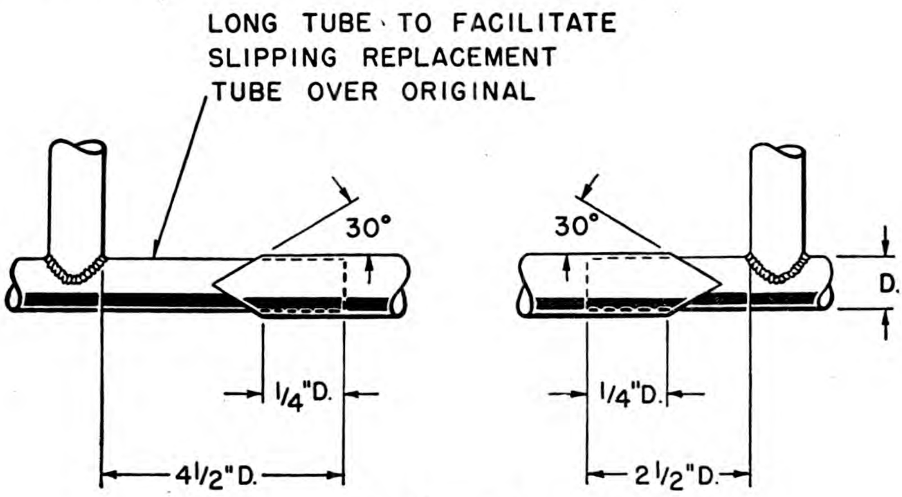


Figure 63.—Larger diameter replacement tube.

Spring the long stub of the original tube a little out of normal position so that you can slip the replacement tube over it. Then pull the replacement tube over the short stub and center it over the cut in the original tubing.

Tack-weld one end of the replacement tube in several places, then weld completely around that end. Let the weld cool completely, then weld the other end of the replacement tube to the original tube.

REPLACING STRUCTURAL TUBING

Maybe a piece of tubing is so badly damaged that you have to replace the entire section. Tube replacement is necessary if the stub of the orig-

inal tubing is too short to attach a replacement or if the splice welds would occur in the middle third of the section of tubing.

Assume one of these conditions applies to the particular job you're on. You look the situation over and decide that the tube will have to be replaced. What next? Use a fine-tooth hack saw to cut the tube CAREFULLY AND COMPLETELY from the structure. Take it easy with that saw. Don't damage nearby tubes or welds.

Where it is apparent that you must make new welds over the location of old ones, chip or file off the old welds completely.

Next, dip the new tube into a hot (165° F.) Paralketone bath and then wipe it from the outside of the tube. The new tube should fit into place with a clearance of 1/32 inch at each end for expansion.

Unless a welding jig is available, you must plan your work to prevent distortion through the progressive (hop-skip) method of welding the joints.

FITTINGS

AIRCRAFT FITTINGS are small attachments which are fastened to tubing members. They may be built up of one or more thicknesses of sheet metal, or they can be forged or machined from bars or billets.

How fittings are welded to tubular parts depends on the load stress they must bear. Those which carry only moderate loads and are not subject to vibration stresses are welded to ONE WALL only of the tube as in (*A*) of figure 64.

If your fitting or lug must transmit high stress, you must weld it to its supporting tube at MORE THAN ONE POINT. Look at (*B*) in figure 64. Here the tube is slotted top and bottom and your fitting is pushed all the way through the tube, then

welded along the length of the slots. This is the *method* used to attach highly stressed fittings which are fastened to a main tube at some point midway between station joints.

On the other hand, suppose you want to attach a fitting to a main tube at a point where brace members terminate as in (*C*) or (*D*). Slot the tubing as in (*C*), and weld the fitting to the tube along the edges of the slots. OR, you can build

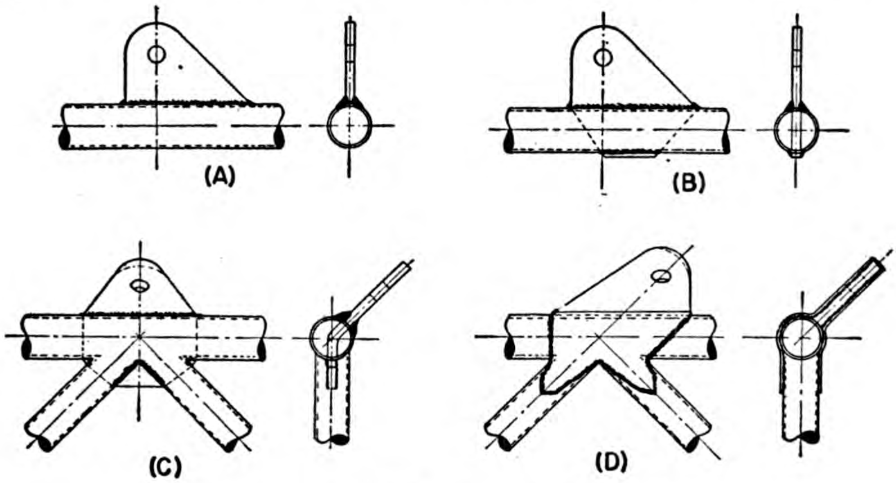


Figure 64.—Types of fittings.

up the fitting in two or three sections with fingers extending to the brace members. In this case, you omit the slotting and simply weld the edges of the fitting to the main tube and brace members as in (*D*).

When you are replacing a broken or worn fitting, caution is your watchword. Don't damage the tube to which the fitting is attached. Pick a replacement fitting having equal or greater physical qualities than the original and copy the original manner of installation when you get ready to put it in.

If the broken fitting is attached to a main tube where a number of trusses terminate, and IF you can't take it out without messing up the struc-

tural members, then cut out the whole section, tubing, fitting and all. This means that you must do two things—first, weld the new fitting to the new section of tubing, and then splice the new section of tubing to the stub ends of the original members.

In figure 65 you see such a repair job. Here a new fitting has been welded to a section of tubing and then the whole section spliced to the original members. Drawings (*A*) and (*B*) of figure 65 show how it is done with internal sleeve reinforcement. Drawing (*C*) shows how it is done by the external sleeve splice method, and (*D*) by the external replacement tube method.

HERE IS THE PROCEDURE FOR REPLACING A FUSELAGE FITTING—

First, support the structure on suitable trestles, line it up, and use clamps or blocks to keep it from slipping out of control while you work.

Next, saw out the section of tubing to which the broken fitting is attached. (You are to assume, of course, that you can't replace this particular fitting without replacing the entire section of tubing to which it is fastened.)

Scratch around now, until you have unearthed a DETAILED DRAWING of the fitting you want to replace. Follow this drawing when you make the new fitting.

Weld your new fitting in place on the NEW SECTION of tubing.

The new section is now ready for you to put into place. Line it up carefully with the main and truss members of the joint.

Now weld it into place. Work progressively from one joint to another, starting with the joints of the main tubing. Don't forget to

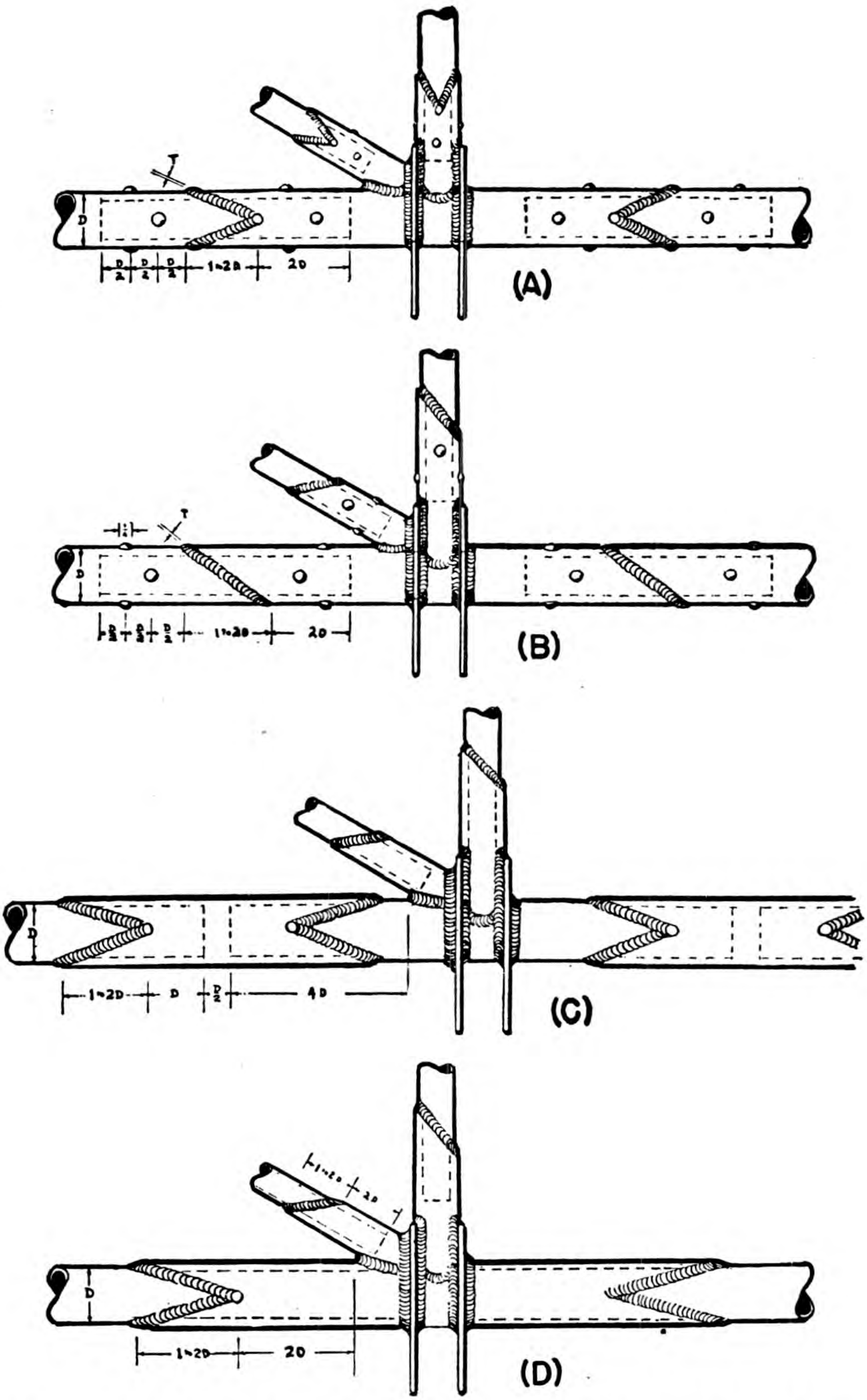


Figure 65.—Methods of replacing members to which fittings are attached.

allow for shrinkage at each joint. LET EACH JOINT COOL BEFORE YOU WELD THE SUCCEEDING JOINT.

HOW GOOD ARE YOU?

After you've finished a repair job on chrome-moly tubing, you should confidently check off each item in the following reminder list.

The weld seam should be smooth and uniform in thickness.

The weld should be built up to provide EXTRA THICKNESS at the seam.

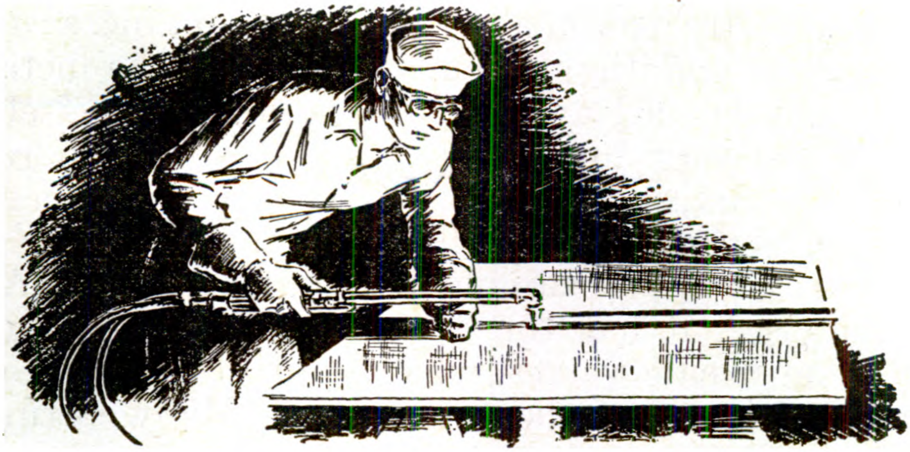
Weld metal should taper off smoothly into base metal.

No oxide should be formed on the base metal at a distance of more than ½ inch from the weld.

The weld must be clean and sound—no blow holes or projecting globules—and nonporous.

Base metal must not be pitted, burned, cracked, or warped.

It is smart strategy to know your stuff so well that this list is second nature to you. Saves you a lot of worry when things start popping and aircraft, which you have repaired, go into action.



CHAPTER 6

CUTTING

FERROUS METALS AND OXYGEN

There are a lot of everyday uses for oxyacetylene flame cutting. It is a quick, cheap way to cut iron or steel where the effect of burning or heating the edge of a piece of metal is not objectionable. The cutting of metals with an oxyacetylene torch is not done on aircraft. But, you'll find plenty of uses for the method in general service work around the shop.

The basis for oxyacetylene cutting is the peculiar reaction of ferrous metals—that is, metals made from iron ore like wrought iron or steel—to oxygen.

Ferrous metals combine with oxygen so readily that the oxygen in the air can start the reaction—witness all the rusty pieces of iron lying around in airplane graveyards. The rust is iron oxide, and the longer a piece lies around the more it is worn away and the more rust it collects.

Cutting iron or steel with an oxyacetylene torch is simply a speeding up of this process, because iron oxidizes much faster when it is hot. Pure

oxygen, if directed on a hot piece of iron, increases the rate of oxidation so enormously that the metal is actually burned away. This action is precisely that which your torch accomplishes when you replace the mixing head with a cutting attachment or when you use a special cutting torch.

Figure 66 is an example of a cutting torch. As you can see, it has the conventional oxygen and acetylene needle valves, which control the flow of the two gases as you heat the metal. Many cutting torches have TWO oxygen needle valves so that you can obtain a finer adjustment of the neutral flame. A cutting torch combines a heating flame with a jet of pure oxygen under pressure. The heating flame preheats your metal to a red heat, and the oxygen jet is directed upon the hot metal to burn it away and thus form a slit known as a KERF, in the metal.

The heating flame in a cutting tip is generally not fed by a single hole as it is in a welding tip, but instead comes out through SEVERAL holes which are arranged in a ring around a larger central hole for the oxygen. The central oxygen tube tapers as it reaches the tip opening to increase the velocity of oxygen.

The high pressure cutting oxygen jet is regulated by an auxiliary oxygen control valve generally operated like a trigger—see the lower drawing in figure 66.

You will usually find FOUR different SIZES OF TIPS for cutting metals of varying thicknesses. There are also special tips for cleaning metal, cutting rusty, scaly, or painted surfaces, rivet washing, and so forth.

In cutting, as in welding, the PRESSURE of oxygen and acetylene and the SIZE OF TIP is governed by the metal's thickness. Table IV shows the approximate pressure for various tip sizes. Better double-

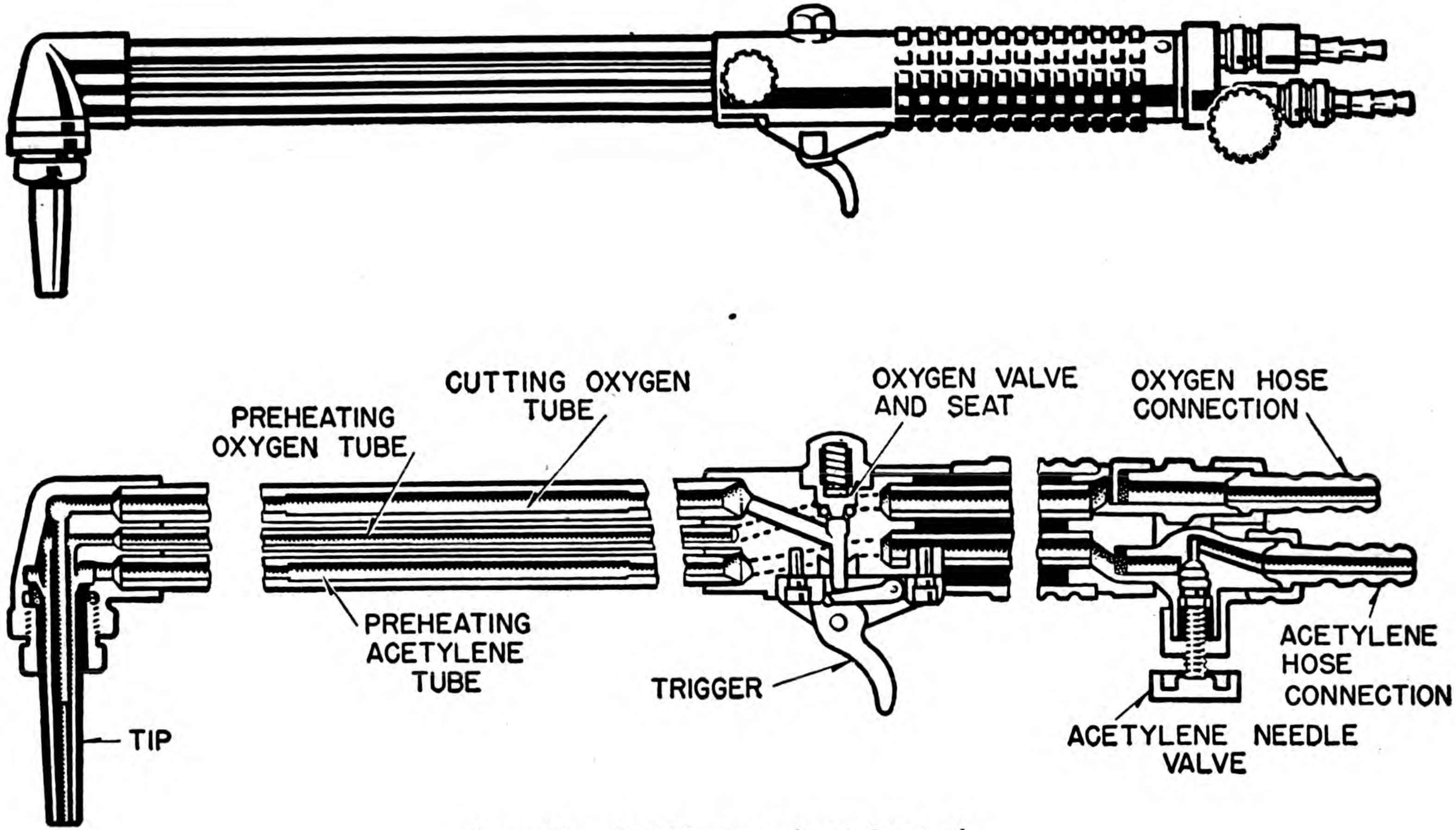


Figure 66.—Metal burner—the cutting torch.

check if possible, by following the pressure recommendations of the manufacturer of your torch. If the steel you want to cut has a heavy coating of rust or scale, you need greater oxygen pressure to make the oxygen burn entirely through the metal.

TABLE IV

Approximate Pressure for Various Tip Sizes

Tip No.	Thickness of Metal, Inches	Acetylene Pressure, Pounds	Oxygen Pressure, Pounds
1	1/8	4	10
1	1/4	4	15
1	3/8	4	20
1	1/2	4	25
2	3/4	5	30
2	1	5	40
2	1 1/2	5	50
2	2	5	60
3	3	6	70
3	4	6	80
3	5	6	90
4	6	7	100
4	8	7	130
4	10	8	150

NOW START CUTTING

Turn on the acetylene needle valve of the torch, light the gas, and adjust for a neutral flame, as in welding. The neutral flame is used in a cutting torch to bring your metal to a kindling temperature. In the case of plain carbon steel, for example, this temperature is 1,400° to 1,600° F.

When you have the neutral flame burning smoothly, try pushing down the triggerlike oxygen

control lever to see what the CUTTING FLAME looks like. When you push down this oxygen control lever, you may find it necessary to readjust the *neutral*, preheating flame to make sure that it REMAINS neutral.

Your first lesson in cutting is best taken on a straight stretch of metal. You can even rule a soapstone guide line on the piece of metal. Draw the line about 1/4 or 1/2 inch from one edge. After you have drawn the guide line, place the piece of metal so that this line is beyond the edge of the welding bench. If you want an exceptionally straight cut, clamp a bar of steel across the piece of metal to guide your torch.

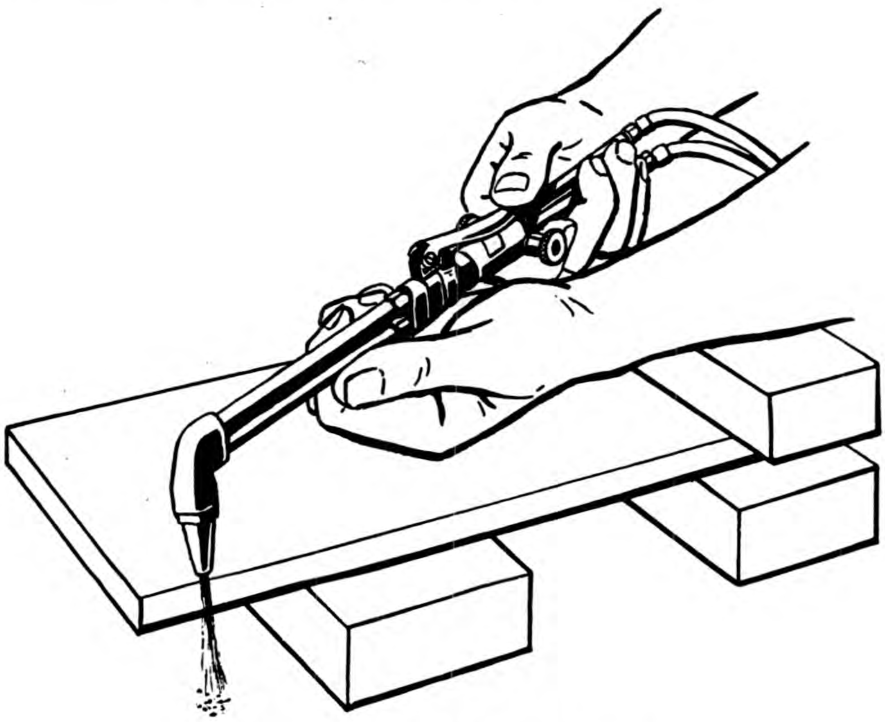


Figure 67.—How to start cutting.

Then, with your preheating flame adjusted to neutral, grab the torch firmly, but not tightly, holding it so that you have instant access to the oxygen control lever. In figure 67, you see how to start cutting a piece of steel. Use your left

hand to guide the torch nozzle while the thumb holding the torch pushes down the oxygen control lever. It is sometimes a help to steady your right forearm or elbow on some handy support, such as the block in figure 67.

The point is to hold that torch STEADY. Naturally, when the cutting tip wavers around from side to side like a car with a woman driver, a wide kerf will result. That's bad. It means a rough cut, slower speed, and greater oxygen consumption.

Now start cutting. As a rule, you begin AT THE EDGE of your piece. Hold the tip VERTICAL (at a right angle) to the surface of the metal. Keep the inner cone about $1/16$ inch from your soapstone guide line and hold the flame there until a spot in the metal turns bright red.

Then gradually press the oxygen control lever and move the torch steadily forward along your guide line to make a fast but continuous cut, as in figure 68. You can tell when the cut is proceeding correctly by the shower of sparks that fall from the under side.

If the cut doesn't seem to go clear through the metal you are probably going too fast. Take your thumb off the oxygen control lever so that the pure oxygen is closed off, and reheat the metal until it is a bright red. You shouldn't have any difficulty starting the cut again when you press down the oxygen control lever.

On the other hand, maybe you are not going fast enough. In this case, the heat of the preheating flame stays too long in one spot, melting the edges of the cut, and you have a very ragged kerf. Speed it up a little.

When you get all through, don't expect the cut section to fall off on the floor. It probably will stick to the main piece, but that's all right.

Your cutting career isn't a failure. It only means that some of the slag produced by the cutting action has bridged across the bottom of the two pieces and on cooling has formed a thin crust which holds them together. This crust is quite brittle,

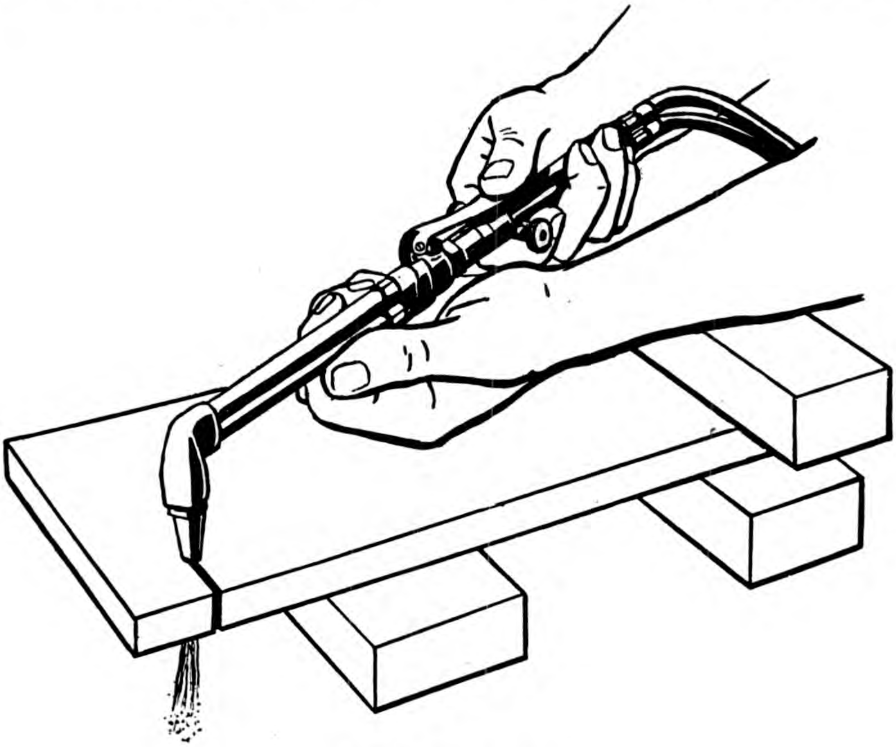


Figure 68.—Still at it.

however, and a smart blow from a hammer will break it and separate the pieces.

SPECIAL CUTTING JOBS

If you're working on a piece where you CANNOT start a cut at the edge but must begin within the piece, plan on a longer period of preheating before you actually start cutting. Then, after a spot is heated to bright red, raise the torch cutting nozzle ½ inch from your work before pushing down the oxygen lever which turns the flame into a cutting flame. After a hole is cut through the metal, it is O. K. to lower the torch

to its normal position, $\frac{1}{16}$ inch from the work, and then proceed.

When a piece of ROUND BAR STEEL like that in figure 69, must be cut, start the cut at the side of the bar, about 90° down from the top. Keep the torch perpendicular to the piece. Gradually lift it to follow the circular outline of the bar as in figure 69.

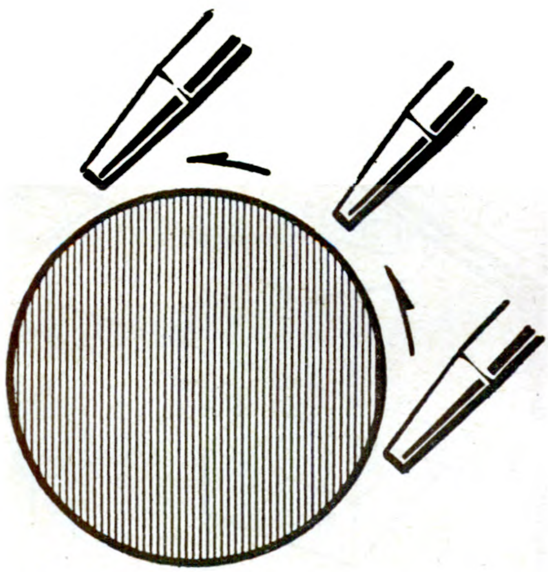


Figure 69.—Torch position for cutting round bar steel.

This vertical position of your torch is also necessary while you descend the other side of the round piece.

Look at figure 70. You see a piece of steel plate that is being BEVELED. Instead of holding the torch vertical, slant it at the correct angle for making the beveled edge. To obtain an even bevel, support the torch by resting the edge of the nozzle on the work, or guide it with a piece of angle iron clamped across the piece as in figure 70.

Maybe you thought when you joined the Navy you'd be making holes in the enemy instead of in steel. The principle is the same. Instead of

pulling the trigger of a gun, you push down the triggerlike oxygen lever of your torch and presto—a HOLE appears. Before pushing down the oxygen lever you must first heat up a small round spot in the steel. Then as you push down

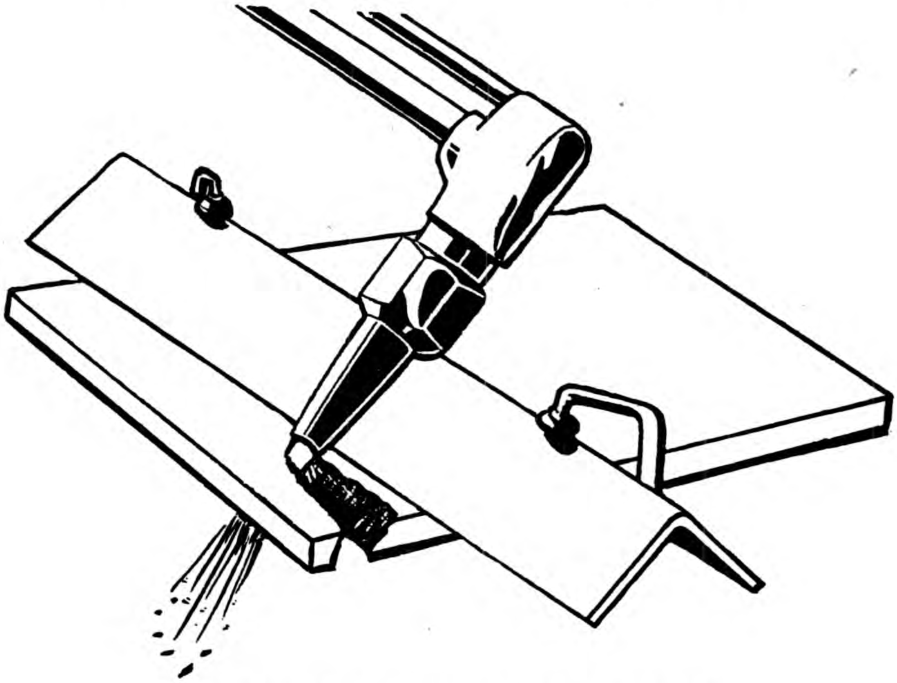


Figure 70.—Beveling steel with a cutting torch.

the oxygen lever raise the torch slightly. A neat hole is left in the metal.

For larger holes, first trace the shape with a piece of soapstone. At some point inside the circle, start a small hole, work the cut out to the line and continue on around the outline.

BEWARE OF SLAG

In all your cutting operations, keep your eye on that hot slag. Globules of hot slag, if they hit any combustible materials lying around, can start a fire before you have time to bat an eye. The drops of hot slag will roll along the floor

for a considerable distance. A good rule is to clear a space for 30 to 40 feet around you. If you can't clear away materials that might catch fire, cover them up with sheet metal guards or asbestos blankets.

It almost goes without saying that you have only yourself to blame if you leave ACETYLENE CYLINDERS where the hot slag can fall on them.

CHAPTER 7

BRAZING AND SOLDERING

MORE WAYS TO JOIN METALS WITH HEAT

So far in this book you have learned how to join two pieces of identical metal by means of filler metal similar to the "parent" metal. By this WELDING process, you form a joint whose characteristics and material are like the original. Welding, however, is not the only way to join metal by the use of heat. The other thermal method of joining metals is called SOLDERING.

Soldering means the fastening together of two like or unlike metals by using ANOTHER metal entirely different from one or both of the base metals. It also means the joining of two metals together without melting either one.

The scientists have figured out that soldering works because the molten solder sticks to the surface of the base metal by means of molecular attraction. A very strong bond is formed because

of this friendliness of the molecules of the solder for the molecules of the base metal.

Some of the most common kinds of soldering include—

Hard soldering done with welding torch:

Copper-tin alloy solder.
Copper-zinc alloy solder.
Silver-copper alloy solder.

Soft soldering done with soldering copper:

Lead-tin alloy solder.

In all of the hard soldering methods you use your oxyacetylene torch as a source of heat. BRAZING, which you are going to be introduced to very shortly, is a hard soldering method which uses a copper-tin (bronze) alloy for solder. Another type of brazing, which will be described later, is the joining of brass parts by the use of copper-zinc (brass) alloy filler rod having a lower melting point than the base metal so that the base metal need not be melted. SILVER SOLDERING uses a silver-copper alloy for the solder.

SOFT SOLDERING, which uses the lead-tin alloy solder requires the use of more specialized equipment.

You do quite a lot of silver soldering and soft soldering on aircraft. Brazing is not done on aircraft but you have to know how, anyway, in order to be able to do general repair servicing of shop equipment.

BRAZING

Brazing is a method of flowing molten bronze from a filler rod over the hot surface of the metal pieces to be joined, thus obtaining a solid bond between the edges of the seam.

The advantage of brazing is that you don't have to melt the base metal. You need only heat the metal to a point a little BELOW its melting temperature. In the case of steel, you can tell when this point is reached by its cherry red color. Metals which lose their original qualities when melted, thus can be joined by brazing without undergoing loss of those qualities.

Brazing is usually the best way to join unlike metals (copper and steel) or to join two pieces of a metal like malleable cast iron (cast iron which has been heat-treated) in which the heat necessary to melt the metal would destroy the heat-treatment. If you braze a joint in malleable cast iron, the base metal does not need to be melted. Result—no loss of heat treatment.

Suppose, for instance, you want to join a piece of cast iron to a piece of steel. The difference in melting points of the two metals, about 450° F., means that when the cast iron is molten, the steel is still solid. If you weld them with a steel filler rod, particles of solid steel will show up in the molten cast-iron puddle. No good. If you braze the two parts, both the steel and cast iron will be only at red heat when the bronze filler rod is molten. The bronze will stick firmly to the cast-iron and steel surfaces and you have a good, strong joint.

Since the base metal is not melted in brazing, your welding process is greatly simplified. The preheating necessary in fusion welding is largely eliminated.

There is one precaution to take in deciding whether to braze a joint. A METAL WHICH WILL BE SUBJECTED TO A HIGH TEMPERATURE LATER CANNOT BE BRAZED. Bronze loses its strength at temperatures of 500° F., or more.

Assume you have decided you can use brazing for a joint. First bevel down the edges of the joint as you would in welding steel. Clean the surrounding surfaces of dirt, rust, and so forth. You must use a BRONZING FILLER ROD and a BRONZING FLUX—borax is O. K.—to obtain a good union between the base metal and the bronze filler metal. Use a neutral torch flame and move it with a slight, semicircular motion.

Heat the surfaces of your base metal and when they reach a cherry red heat (in the case of steel) heat the bronzing rod and dip it into the can of flux. You will find that enough flux adheres to the rod without your having to sprinkle any of the flux over the surface of the metal.

Now, bring the filler rod near the tip of the torch and let the molten bronze flow over a small area of the seam. Build this surface up to the required height. Then move the torch forward and repeat the process.

Watch carefully to see that you don't heat up the base metal past the cherry red stage. If you get careless on this score, the bronze will boil when it is added and the low melting point alloys of the bronze will burn out, leaving the bronze porous and brittle. On the other hand, if the base metal is NOT HOT ENOUGH, the bronze won't flow smoothly. Instead, it forms elusive drops which have a neat trick of rolling off as fast as the bronze is applied.

After you finish the weld, let it COOL SLOWLY.

BRASS

WELDING OF BRASS is actually done most efficiently NOT BY WELDING, BUT BY BRAZING. The reason is that the most effective way to join brass is to use a brass filler rod of SLIGHTLY LOWER MELT-

ING point than the base metal. Then the base metal need not be melted. In other words, you BRAZE it.

Brass is the metal which, in its simplest form, is an alloy of copper and zinc although other metallic elements are often added to improve its characteristics. Naval brass, one of the best of these alloys, consists of 62 percent copper, 0.5 to 1.5 percent tin, 0 to 0.10 percent iron, 0.20 percent lead, and the remainder zinc. Its three advantages are high strength, toughness, and resistance to corrosion. It comes in bar, plate, rod sheet, and strip form and in the soft, half-hard, and hard condition of temper. Brass has few uses in aircraft except for pipe fittings. Consequently most of the brazing you do will be in connection with general repair work on shop equipment—not on aircraft.

Your torch flame with brass should have a slight EXCESS OF OXYGEN—ONE OF THE VERY FEW INSTANCES where an oxidizing torch flame is not to be avoided like the plague. You have to be especially careful in applying heat to brass in order not to burn out or oxidize the zinc content of the brass.

Use a FLUX. Any good commercial brazing and welding flux is all right. In a pinch, borax diluted with boric acid or sodium carbonate may be used. Apply it by dipping the hot end of your filler rod in dry flux, or by painting the dissolved flux on the rod. Flux protects the hot metal from the air and other gases by forming a film over it. In addition, flux cleans the hot brass of oxides formed during the welding process.

The filler rod for welding brass should have approximately the same composition as the base metal. As was pointed out earlier, a rod with a slightly lower melting point than the base metal

gives the best results. Tobin bronze and manganese bronze are both trade names for brass filler rods which are good.

You can use the same joints in brazing brass as in welding. Be sure to clean the surfaces with a file or sandpaper. And don't forget to allow for expansion and contraction. Thick pieces of brass must be beveled. BEVELING should be done mechanically BY FILING or some other method. Don't bevel brass by melting or cutting because then the zinc in the brass is lost. To reduce the amount of heat required to do the actual brazing, preheat any heavy brass parts. This precaution also lessens the danger of warping.

SILVER SOLDERING

SILVER BASE SOLDERS, known as "hard" solders, are used in aircraft work to repair oil coolers, coolant radiators, and other parts which have to withstand vibration and high temperatures. Silver solder is used quite a lot to join copper and its alloys, Monel metal, nickel and silver, as well as various combinations of these metals.

You can get silver solder in several different grades depending on the silver content which ranges from 14.5 to 66 percent. The melting points vary from 1,160 to 1,600° F. The standard forms of silver solder are strips and wires, but it is also made in rod form.

If you have a set-up where the solder can be placed in the joint before you apply heat, you use the STRIP FORM. For joints where it is best to apply the solder after heating, you use the WIRE FORM.

THINGS TO REMEMBER

FLUX has to be used in all silver soldering because of the necessity for having your base metal

chemically clean without the slightest film of oxide to prevent the silver solder from coming into intimate contact with the base metal.

A paste flux is used generally in most silver soldering. If you don't have a prepared flux handy, a mixture of 12 parts of borax and 1 part of boric acid is all right for high-melting point silver solder. Prepared flux begins to melt at 800° F., becomes fluid at 1,100° and remains stable up to 1,600° F. It must melt at a slightly lower temperature than the solder. As a matter of fact, when you see the flux start to flow freely you know it's time to apply the solder.

You must be as conscientious about CLEANING the metal at a joint to be silver-soldered, as you are about your uniform for Captain's inspection. The joint MUST BE perfectly clean. Which means not only physically clean—minus all dirt, grease, oil, and paint—but also chemically clean—minus any oxide film. After you have removed the dirt, grease, and paint, remove any oxide which may be present by grinding or chipping the piece until bright metal shows. During the soldering operation, the flux you use continues the process of keeping oxide away from the metal.

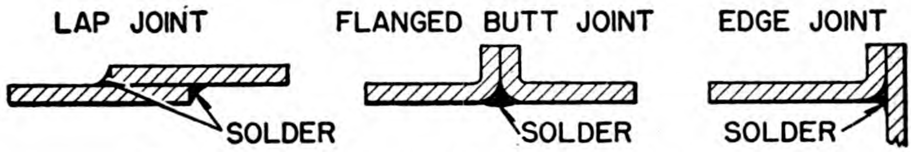


Figure 71.—Recommended joints for silver soldering.

See that the edges of the joints are smooth and fit tightly. Only a FILM of silver solder is usually needed for a sound joint. You don't add strength to the joint and you waste expensive solder IF you use silver as a filler metal.

Now figure out WHAT KIND OF A JOINT TO USE. Look carefully at figure 71. Here are three

recommended types of joints for silver soldering. Where the metal can be formed to give a seam wider than the base metal thickness, as in the flanged, lap and edge joints, you have the best kind of joint for bearing up under all kinds of loads. If you use a lap joint, figure the amount of lap according to the strength needed in the joint. Here is a handy rule of thumb.

> For strength EQUAL TO that of the base metal in the heated zone, the amount of lap should be four to six times the metal thickness for sheet and small diameter tubing.

GO AHEAD

The oxyacetylene flame for silver soldering must be either NEUTRAL or have a SLIGHT excess of acetylene. It must be soft—not harsh. During both preheating and application of the solder, hold the tip of the inner cone of the flame about ½ inch from your work. Keep that flame moving so as not to overheat your metal.

If the piece is large, be careful to PREHEAT a considerable area around the joint before you apply the solder, especially if the base metal conducts heat rapidly. And if you are soldering two pieces which have different thicknesses or which conduct heat with unequal speed, you've got more worries. Because then you must gage the preheating so that BOTH parts reach the soldering temperature at the same time.

When you have both parts of the base metal at the right temperature start using the solder. Apply it to the surface of the UNDER OR INNER PART at the edge of the seam. Don't forget your flame meanwhile. You have to do two different things at once. Direct the flame over the whole

seam and keep MOVING IT so the base metal remains at an even temperature.

SOFT-SOLDERING

Soft-soldering is used for copper, brass, and coated steel in combination with mechanical seams—that is, seams that are riveted or bolted. It is also used where a leakproof joint is wanted. It is sometimes used for fitting joints to promote rigidity and prevent corrosion, but it is doubtful whether such a soft-soldering job is of much value. In any event, it is done on only very minor repair jobs.

Soft solder yields gradually under a steadily applied load and should not be used unless the loads transmitted are very low. It SHOULD NEVER BE USED AS THE SOLE MEANS OF ATTACHMENT OF TWO STRUCTURAL MEMBERS.

THE SOLDERING COPPER

You may already be familiar with the SOLDERING COPPER which you use to do soft soldering. It is made of a square or octagonal SOLID COPPER BAR

Figure 72.—A soldering copper.

with a four-sided, tapered point. The copper is fastened, as in figure 72, by an iron rod to a wooden handle. The purpose of a soldering copper, of course, is to act as a source of heat for the soldering operation. The copper metal is extremely efficient at this job because it is an excellent conductor of heat and is also very easy to coat with solder.

Some soldering coppers have a built-in heating element like the ordinary electric iron. All you have to do is plug it in an electrical outlet. The copper in figure 72, on the other hand, requires heat applied from the outside.

The soldering copper produces a very concentrated heat so that you can spread and smooth the solder as it is melting. But a soldering copper DOES have a couple of disadvantages. It must be reheated often and the tip must be cleaned occasionally. The cleaning process and the process of applying solder to the copper are known as "TINNING."

TINNING THE COPPER

To tin the copper, you first must heat it to a bright red and then clean the point by filing until it is smooth and coppery. There must be no dirt or pits left in it. Next, clean the point CHEMICALLY by dipping it into a cleaning compound, by which time the copper should not be more than a dull red. Then apply the solder. You CAN combine these last two operations by melting a few drops of solder on a block of sal ammoniac (cleaning compound) and then rubbing the soldering copper over the block until the tip is well coated with solder as in figure 73.

If the point of your soldering copper doesn't suit you, you can shape it up (forge it) while red hot by using a heavy hammer. Then file it and apply the cleaning compound as usual.

As you use the copper in soldering, you must remember to dip the point occasionally in a solution of 1 part of sal ammoniac to 30 parts of water. (Keep this solution in an earthenware jar.) If you don't happen to have sal ammoniac around, powdered rosin will serve. Put some

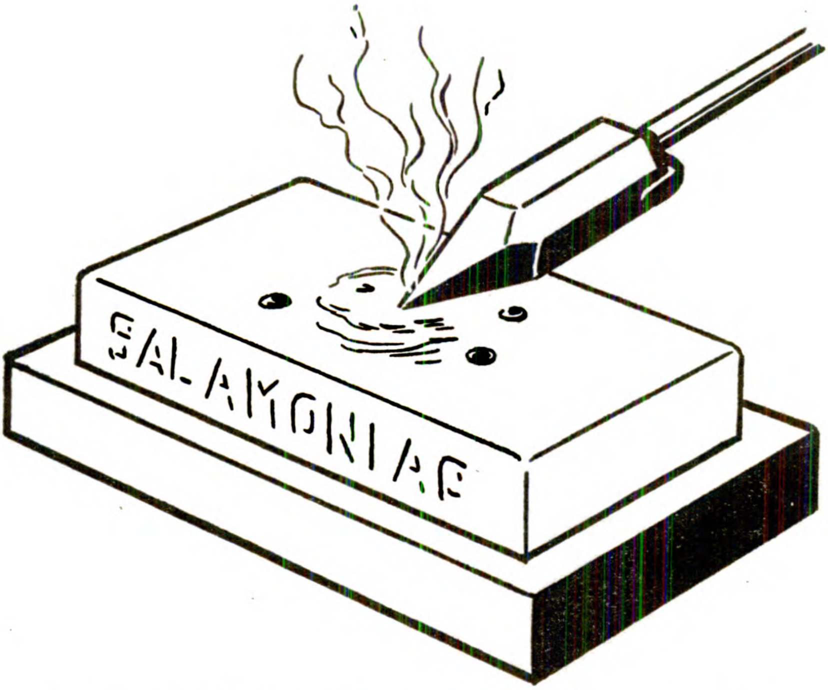


Figure 73.—Tinning a soldering copper with sal ammoniac.

rosin on a board or brick and stop once in a while to rub the hot soldering copper over it as in figure 74. Then drop some solder on the rosin,

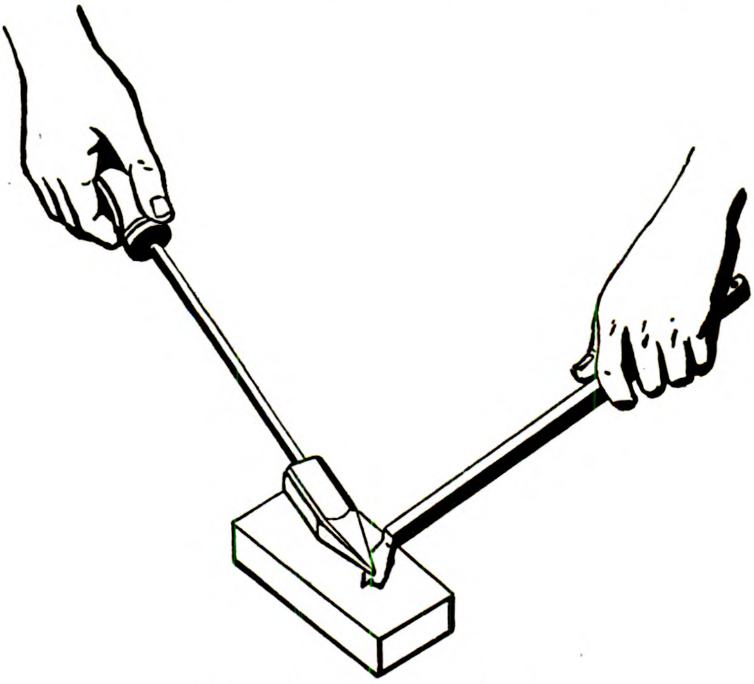


Figure 74.—Tinning with rosin.

rub the copper over the solder until it is well-coated, and continue your work.

Soldering coppers are heated by means of either a GAS OR CHARCOAL FURNACE, or by a GASOLINE BLOWTORCH, which you must know how to operate.

WARNING—Don't overheat the soldering copper because too much heat burns off the tin. You'll have the whole tinning process to do over again.

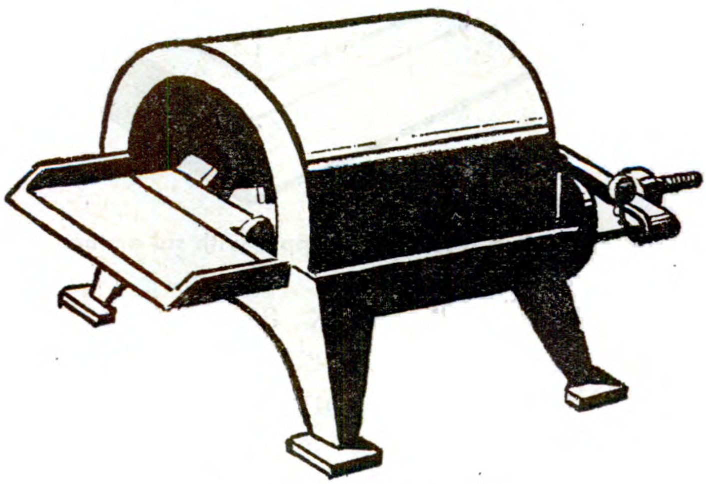


Figure 75.—Gas furnace.

Look at figures 75 and 76. Figure 75 shows a common gas furnace. Figure 76 shows a GASOLINE BLOWTORCH.

SOURCE OF HEAT—THE BLOWTORCH

Here is how a blowtorch works. The tank of the blowtorch should be filled about two-thirds full of clean, UNLEADED gasoline. Do you see the knob on top of the tank in figure 76? That is the handle of the pressure pump. The other handle sticking out to the left in figure 76 belongs to the valve which controls the flow of gasoline from the tank to the nozzle (the tube

with the holes in it). After turning the valve handle to open the valve a little, you pump up the air pressure in the tank to a point where the gasoline will flow up into the nozzle. Hold a piece of scrap metal over the end of the nozzle to prevent the gasoline from squirting out in a stream. Since the blowtorch is still cold, the gas drips out of the holes in the nozzle in LIQUID form. The priming pan, which sits under the nozzle, catches these gasoline drippings.

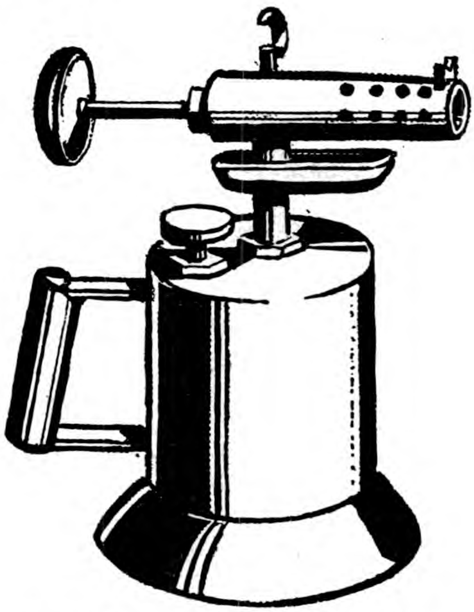


Figure 76.—Gasoline blowtorch.

Wait until the priming pan is partly full of gasoline, then close the valve. Now light the gasoline in the pan. When the flame has heated up the nozzle, open the gasoline valve again slightly. The gasoline now becomes vaporized as it strikes the heated nozzle, and the vapor flowing from the open end of the nozzle is set on fire by the burning gasoline in the priming pan. Now all you have to do is balance your soldering copper on the holders attached to the top of the blowtorch nozzle, adjust your flame by means of the valve, and wait for the copper to get hot. The

flame of the torch, when adjusted, should be blue in color. If yellow appears in the flame it is probably due to either insufficient preheating of the nozzle or dirty jets in the valve.

FLUX FOR SOFT SOLDERING

If the base metal is one that oxidizes slowly, and if you keep it at the correct soldering temperature, you can usually use a coat of tallow, rosin, or some similar substance as FLUX on the freshly cleaned surface. The only requirement in such soldering is that the flux be present to keep oxides from forming during the actual soldering process. Flux is not needed to REMOVE oxides already present.

It's a different story, however, IF the base metal surface or the solder is covered with an OXIDE FILM. Oxide is about as welcome in a soldered—or welded—joint as ice on an airplane's wings. Oxide film can be removed from most metals with zinc-chloride flux.

For grade A soft-solder (99.65 percent tin and lead) which is best for airplane work, either rosin, zinc chloride (cut acid), or a rosin-glycerine-steric compound can be used. For use with grade A soft solder on galvanized iron or zinc, however, hydrochloric acid (raw acid) is a better flux than zinc chloride. Whatever flux you choose must be thoroughly cleaned off after soldering.

In soldering ELECTRICAL CONNECTIONS and other parts that must be kept free from corrosion, use ROSIN, or some other NONCORROSIVE FLUX.

Soft solders melt at comparatively low temperatures and can be used for soldering most commercial metals. Soft solders are made chiefly of TIN AND LEAD and can be obtained in bar, wire,

pig, or granulated form. The melting point of tin is about 450° F., that of lead, 620° F. Yet when they are alloyed in equal proportions, the melting point of the alloy is only 360° F.

The film of solder between the surfaces of a joint should be kept thin in order to give the strongest joint. Excess solder is wasteful, ugly, and doesn't add to the strength of the joint in the least.

There are three things to do in order to have a good soldered joint—the parts to be joined must be CLEANED THOROUGHLY, the joint must be FITTED CAREFULLY and you must use the RIGHT KIND OF FLUX.

The kinds of flux for soft-soldering have just been described. Now remove all scale, dirt, and oxides by scraping, filing or brushing with a wire brush. After you have cleaned the metal, fit the parts tightly into place and coat the joint with flux. Then apply the hot, tinned, soldering copper and the proper amount of melted solder. Unless the metal is new and bright, you should add a little flux during the process to remove any oxides that may form and also to help along the melting of the solder you have applied.

NOW TRY IT

The application of the melted solder requires somewhat more care than you might guess. You have to do more than daub a little solder in a crack. You AREN'T plugging holes in a milk pail, you know. Unless the parts are locked together or are held by rivets or some other mechanical means, you must hold them together by means of a bar of solder, or a piece of steel or wood in one hand while you tack the seam with the other hand, as in figure 77. To tack the seam, touch

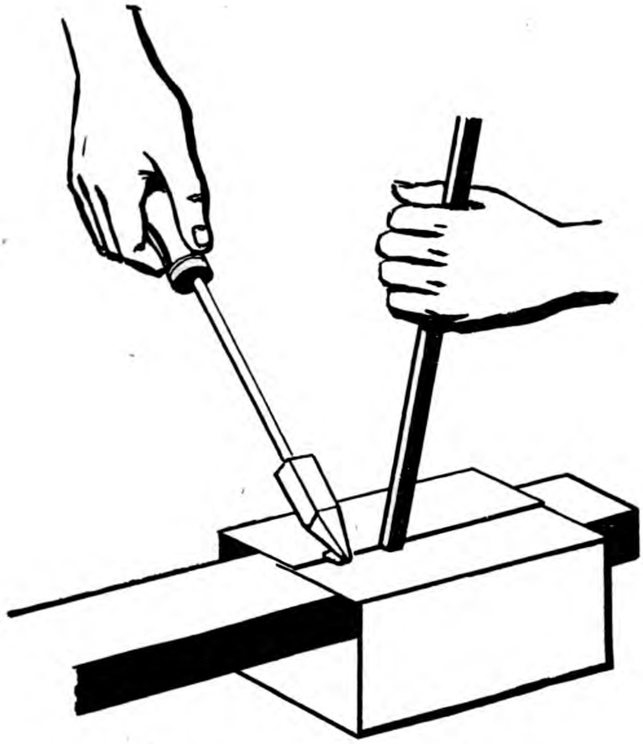


Figure 77.—Holding the parts together.

the hot soldering copper to a bar of solder. Then use the drops of solder which stick to the copper to tack the seam at a number of points as in figure 78.

Now that the seam is tacked so that it won't slide around, go ahead and finish soldering. Take

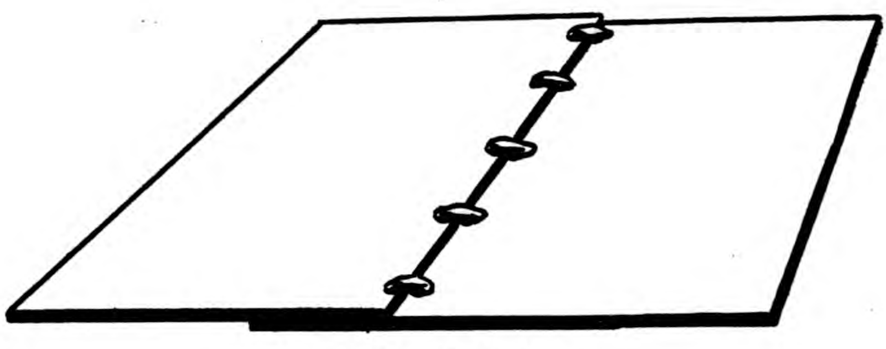


Figure 78.—Tacked seam.

a hot well-tinned soldering copper and hold it so that the POINT of the copper extends over a single thickness of the metal at the seam, while the BACK of the copper extends over the seam proper at a

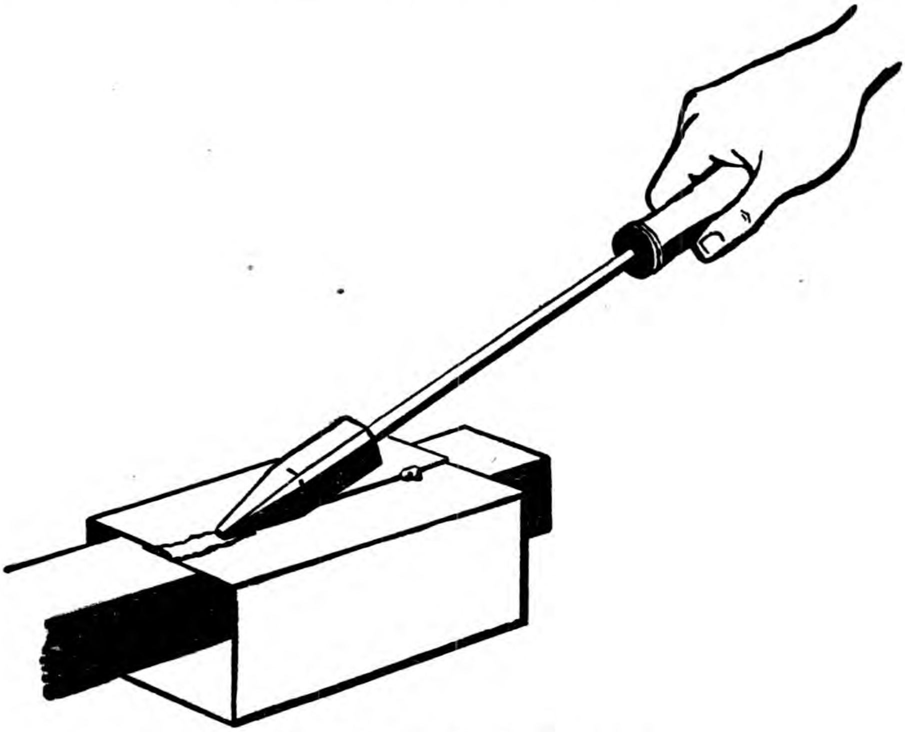


Figure 79.—Soldering a seam.

45° angle as in figure 79. Hold the hot copper in this position while you touch a bar of solder to the point. As the solder melts, draw the copper slowly TOWARD YOU at an angle along the seam as in figure 79. Add as much solder as necessary without raising the soldering copper from the job. The melted solder should run between the surfaces of the two sheets the FULL WIDTH of the seam. Make as long a stroke as possible before your soldering copper gets cold. Then, after remelting the solder at the point where you stopped, go on from there. The best seam is produced without removing the soldering copper from the surface of your work.

There is another kind of soldering known as SWEATING, in which you TIN BOTH SURFACES of the pieces to be joined, then hold them together and heat them with a soldering copper or blowtorch until the solder melts and begins to run out. You must keep the parts in close contact by pressure until the solder cools and sets.

GIVE IT A BATH

Whether you're doing hard soldering or soft soldering you must clean the joint when you're through. This means getting rid of all flux that might be left sticking around to cause corrosion or prevent paint from adhering. In some cases, you also immerse the joint in a "bright dip" to restore the color.

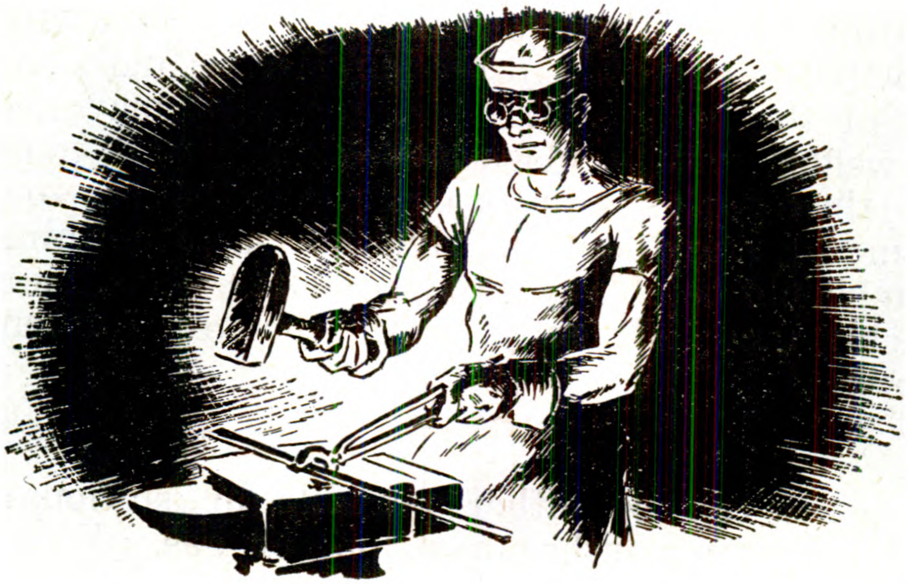
If the base metal is nonferrous—that is, NOT made from iron ore—a good solution for removing flux consists of 1 fluid ounce sulfuric acid, 1.5 ounce sodium bichromate and 1 gallon of water.

Boil FERROUS METALS in a 10 to 15 percent solution of caustic soda for 30 minutes to get rid of flux.

In either case, rinse the metal thoroughly in clean water after treating it.

Sometimes you may want to restore to its original color metal which has been discolored by heat. The color of copper and brass particularly seems sensitive to heat. The remedy is a "bright dip" consisting of 68 fluid ounces sulfuric acid, 20 fluid ounces nitric acid, 0.12 fluid ounce hydrochloride acid, and 40 fluid ounces of water. Then rinse the metal thoroughly in clean, running water.

Scale which is caused by the heating of steel parts is best removed by a LIGHT SAND BLAST.



CHAPTER 8

BLACKSMITHING

"THE SMITH A MIGHTY MAN IS HE—"

Maybe you don't have "large and sinewy hands" like the village blacksmith in Longfellow's poem. Regardless of the size of your hands, however, you may find that you must do some blacksmithing in the course of your career as an Aviation Metalsmith.

For example, you often need specially shaped tools, such as rivet sets, bucking bars, dollies and chisels in the repair of metal aircraft parts and assemblies. It is possible that such tools might not always be on hand. And, anyone who can do simple blacksmithing can make such tools easily and quickly.

BLACKSMITHING CONSISTS, ESSENTIALLY, OF HEATING IRON AND STEEL UNTIL YOU CAN SHAPE THEM BY HAMMERING OR POUNDING. Iron or steel in this condition is said to be plastic or "workable." You heat the metal by means of a FORGE or, if you don't have a forge, by means of your

welding torch. And you use tools such as ANVILS, HAMMERS, and TONGS in the hammering and shaping of the hot metal. Iron and steel may also be welded with a blacksmith's forge and tools, but these welds aren't particularly satisfactory from the standpoint of aviation metalsmithing. You should be able to produce better welds, more quickly and efficiently, with the oxyacetylene process.

FORGES

Forges can be either portable or stationary and may burn either coal, oil, or gas. Forges fired by either oil or gas are pretty simple to use and you ought not to run into much trouble with them. The principle on which these forges work is very much the same as that of an oxyacetylene blowtorch. That is, you must regulate the supply of fuel and air so as to obtain a nonoxidizing fire in the forge—one which will not cause scale to form on your metal and leave it with a rough, pitted surface.

Coal-fired forges, however, are something else again. You have to obtain a satisfactory fire (nonoxidizing) by means of the fuel (coal or coke) and the air which is supplied to the fire from a blower. The blower is usually a part of the forge, although in some cases, the blower may be eliminated by connecting the forge to the ship or shop air line.

Figure 80 is a picture of a typical, coal-burning portable forge in which you build a fire to heat your work to the right temperature for forging. It consists of an iron FIRE POT lined with fire clay or some other material which holds the heat in. You build your coke fire in this fire pot where it burns with the help of air which enters through a hole at the bottom of the fire pot called a TUYERE.

The forge in figure 80 has a hand-operated blower at the left. However, motor-driven blowers are sometimes used.

The HOOD over the fire pot collects the gases flowing through the fire and keeps the smoke and

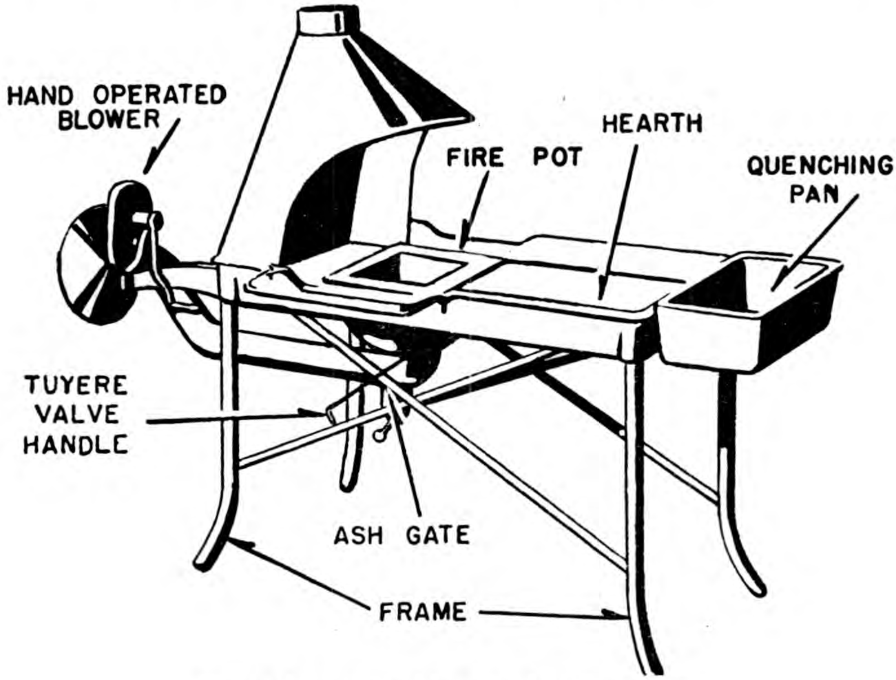


Figure 80.—Portable, coal-burning forge.

spark situation well in hand. A water tank—called a quenching pan, cools your work.

THE FORGE FIRE

It's up to you to make the fire burn. A COAL-FIRED FORGE has a couple of things in common with the furnace back home. First, it requires a certain amount of skill on your part to build and control a good forge fire. AND, you have to feed it a good grade of coal. In blacksmithing, you want a grade of coal which will form the right kind of coke as it burns. The fuel actually burned for each job is coke saved over from a previous fire.

THIS IS THE WAY IT WORKS—

Say you are going to build a SIDE-BANKED fire.

(There are two other types, PLAIN OPEN, and HOLLOW—but they aren't as well-adapted to your kind of work.) The first thing to do is to clean out any coke, ashes and clinkers from previous fires which may be in the fire-pot. Throw away the ashes and clinkers BUT NOT the coke. Remember, the coke is what you use for fuel. Now, take a piece of wood, wide enough to cover the tuyere at the bottom of the firepot. The length and height of the block depend on the size of the fire. Place the block in the fire pot over the tuyere so that you are looking along the length. Now pack wet, green coal ("green" coal is coal that hasn't been burned) on either side of this block as in figure 81, to bank

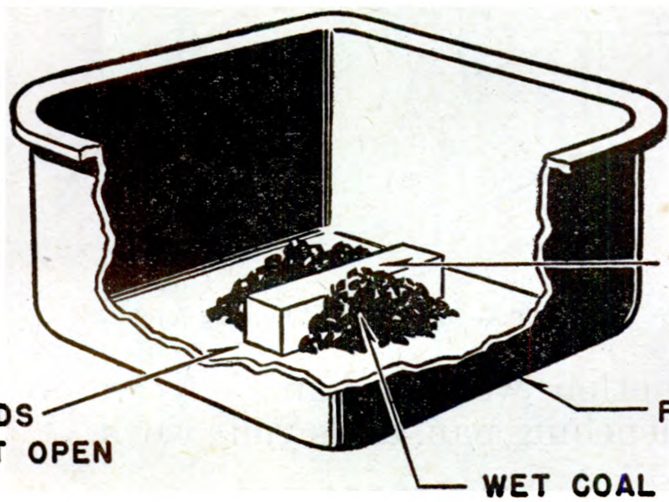


Figure 81.—Preparation for side-banked type of forge fire.

the fire. Then take away the block and round the banks of coal by hand along the top edge.

Next put wood shavings in the troughlike space left when you removed the block and light them. As soon as you have a healthy little fire going with the shavings, ADD THE COKE which you saved from the previous fire. At this point, you must start the air blast through the tuyere in order to get the coke to burn.

Now your forge fire should be burning smoothly. From here on, all you have to do to control the fire, is to regulate the supply of air coming up through the tuyere and add coke every so often.

The wet, green coal which you have banked up around the fire will be turned to COKE by the heat of the fire. DON'T push this coke into the fire, but salvage it after you've finished. You'll use it for fuel in the next fire.

The thing to remember about your forge fire is that you want NEUTRAL, NONOXIDIZING fire just as you wanted a neutral torch flame for welding. You must make sure that ALL OF THE OXYGEN in the air supplied to your fire is consumed. Otherwise the oxygen will attack the metal and form a scale or oxide.

In addition to keeping a sharp eye on the amount of air coming in through the tuyere, you should use SMALL pieces of coke in the fire. Small pieces provide fewer passageways through the fire for air. Consequently there is less danger that air will hit the iron or steel before the oxygen in the air is burned out.

To obtain a nonoxidizing fire, you must not only control the amount of oxygen supplied to the fire but you must also take considerable pains with the placement of the parts to be heated. The best scheme for placing the pieces of metal is to brush back the top layers of the burning coke so as to leave a big enough space for your piece of metal. Remember to leave enough coke at the bottom of the fire pot, to furnish the right amount of heat under the parts. Now cover up the parts with the coke you brushed aside.

This method for inserting your metal parts into the fire has been devised to help you keep a nonoxidizing fire around the parts. Simply poking the metal part into the fire IS NOT "just as good."

NEVER USE GREEN COAL to cover up the parts to be heated.

If you have an OIL-BURNING, STATIONARY FORGE, you will find that VALVES control the air and oil pipes. In starting up an oil-burning forge, always begin by giving the burner a little air. Then apply the light—preferably a piece of lighted waste. See that there is enough flame to set the oil on fire and then open the oil valve until you have a good flame.

After a few minutes, more air can be turned on. Then, gradually, more air and more oil are added until the right heat is obtained. When you want to stop or shut off the burner always TURN OFF THE OIL FIRST. THEN shut off the air.

Your goal with an oil-burning forge is a clear, non-smoky gas flame in the heating chamber. A lot of black smoke is a sign you're using too much oil.

YOUR TOOLS

The tools you use in blacksmithing are pretty simple in design and fairly easy to use. All of those described here may not always be available at the base where you are stationed. But you should have at least a speaking acquaintance with them. They include an ANVIL and various types of HAMMERS, SLEDGES and TONGS.

Figure 82 shows the common garden variety of blacksmith's anvil. At one end, it has a HORN (*A*), around which you can bend metal parts.

The body of the anvil is made of wrought iron, high grade cast iron, or cast steel. The face, or top portion, of the anvil must be hard enough to resist all ordinary hammering but not brittle enough to crack or chip under hammering.

Wrought iron anvils usually have a hardened steel face, welded on. Cast iron or cast steel an-

vils do not have this added face. Instead, a chilling plate is inserted in the mold before the anvil is cast. This gives the face of the anvil the necessary hardness.

At the right-hand end of the anvil there is a square hole (*E*), called the HARDIE HOLE, which holds cutting and forming tools like the bottom swage, or the hot or cold hardie. The other hole is small and round and is called the PRITCHELL HOLE.

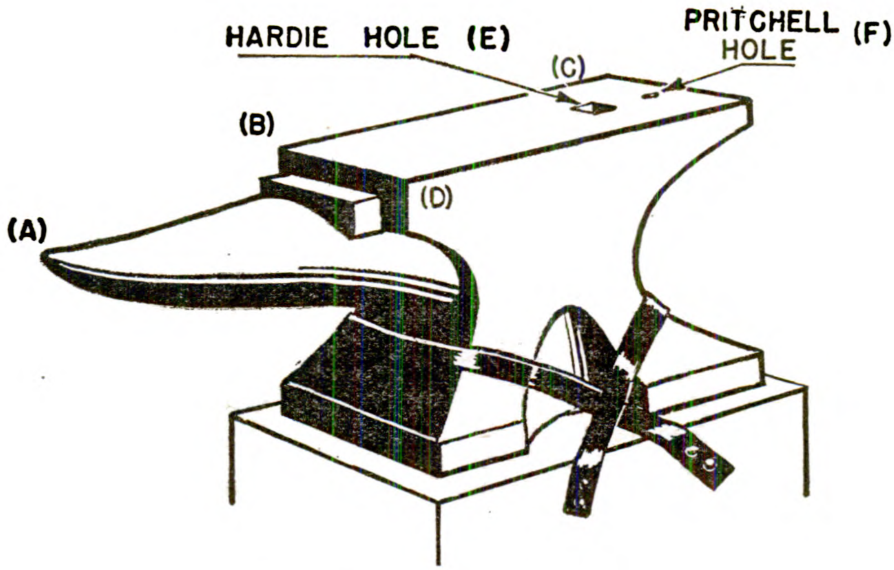


Figure 82.—Blacksmith's anvil.

(See (*F*).) When you want to make a small hole in a piece of metal, you punch the core of it out through the Pritchell hole.

It is important to mount your anvil adequately. An excellent mount is a solid oak block. If you work quite a lot with soft metals, it is a good idea to put a sheet of leather or felt between the bottom of the anvil and the mounting block to absorb some of the shock of the hammer blows. You can secure the anvil by using iron straps, like those in figure 82. A good way to judge whether the anvil is mounted at the right height is to

stand beside it with your arms hanging down at your sides. Your knuckles should be horizontally opposite the anvil's face.

You may already know something about the tools used in sheet metal work, but most of those tools aren't suited to blacksmithing.

First, a small review of hammers in general—how they're made and what they are used for.

HAMMERS

HAMMERS are classified according to weight—hand hammers, hand sledges, and swing sledges—and according to peen. The peen of a hammer

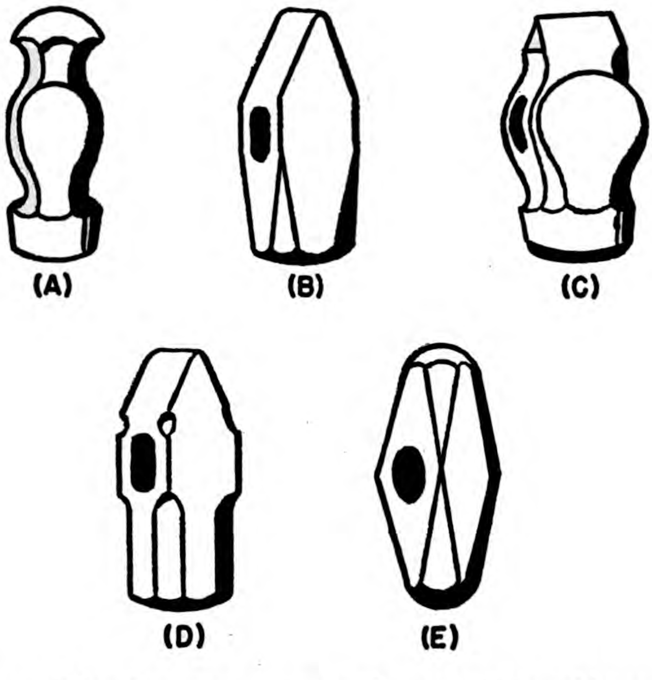


Figure 83.—Hammer type according to weight and peen.

refers to the shape of the top or back surface of the head OPPOSITE the working surface, or face. Thus, a hammer may be BALL-PEEN, as (*A*) of figure 83, CROSS-PEEN, as (*B*), or LONG-PEEN (sometimes called STRAIGHT-PEEN) as (*C*).

The ball-peen hammer, as you can see, has a ball-shaped peen, or back face. You use this type of peen when you want to stretch the piece of metal in length and width. You use the cross-peen hammer when you want to stretch the metal lengthwise BUT NOT crosswise. The long-peen, or straight-peen, hammer is used when the metal is to be spread sidewise.

The HAND HAMMER is intended for use with one hand. Consequently, the head ought not to weigh more than 2½ pounds. A 1-pound head is a normal, convenient weight. The handles of hand hammers are usually 15 to 16 inches long and fit your hand easily.

A hand sledge is considerably larger than a hand hammer. The head usually weighs from 5 to 8 pounds while the handle is from 26 to 34 inches long.

In figure 83 (*D*) you see a typical HAND SLEDGE HAMMER. This type of hammer is used by your helper to strike "shoulder" blows. That is, he hoists the head of the sledge to his shoulder and strikes from that position. Both large hammers and sledges are often called flogging hammers because they do only heavy work.

For striking exceptionally heavy blows, your helper uses a mean-looking baby like the SWING SLEDGE shown in figure 83 (*E*). It gets its name from the fact that the helper grasps the handle near the end (it is about 3 feet long) and delivers a full arm swing blow. Thus the head of the sledge, weighing 8 to 20 pounds, passes through a rather wide arc.

In order to be sure the hammer hits the correct area of the part, you may employ a SET HAMMER. This tool is first set, or placed, upon the point where you want the blow to fall. You hold the set hammer in position while your helper delivers

the necessary number of blows with a hammer or sledge upon the peen (the back face) of the set-hammer head.

The set hammer is also used to give some part of the work a definite form which cannot be obtained by hammering directly upon the work. Variously shaped heads are fitted on set hammers to accomplish this purpose.

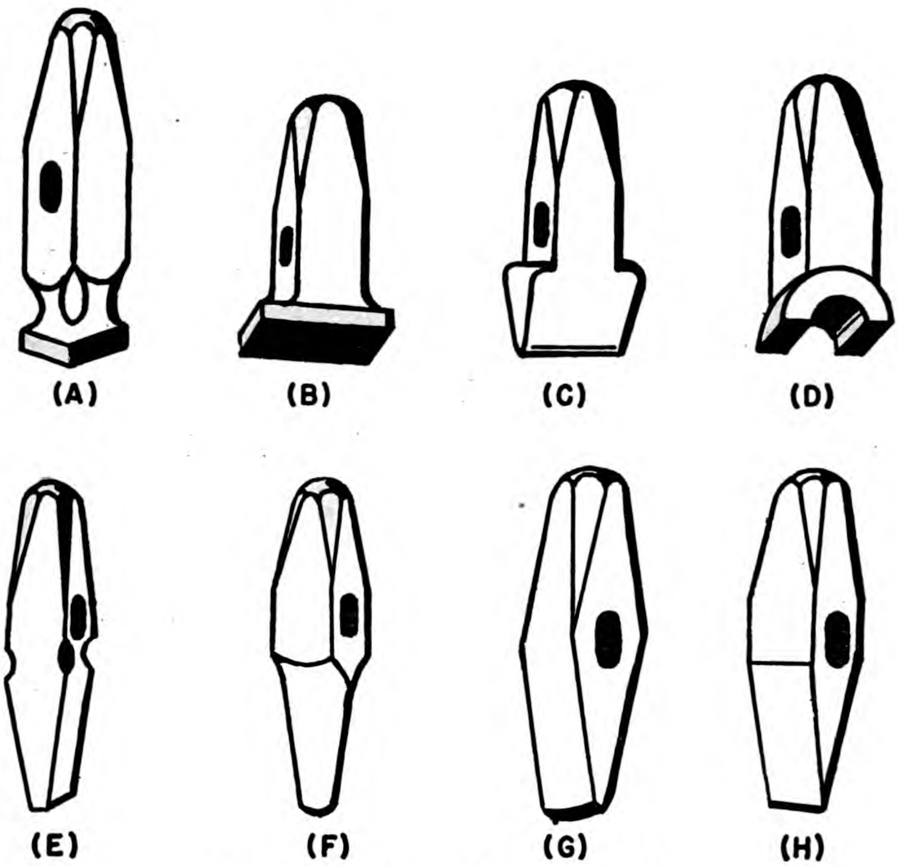


Figure 84.—Types of hammer heads.

The SQUARE-HEADED SET HAMMER, shown in (*A*) of figure 84 is used to produce a flat surface, or to make a square shoulder or projection. A FLATTER, the head of which is shown (*B*) is used for the same class of work as the square set hammer. But the flatter has a larger face than the square-headed set hammer, as you can see. For this reason the flatter is used in finishing to flatten down a surface.

The FULLER, (*C*) in figure 84, is the set hammer head used in spreading the metal. Because of its shape, the fuller head concentrates the force of the sledge blow on a small surface and therefore makes it more effective at that particular place. Its effect is much like that of the straight-peen hammer.

The COLLAR TOOL, also known as a TOP SWAGE, is the grooved drawing (*D*). It is used to shape bars and rods into circular, hexagonal (six-sided) or octagonal (eight-sided) sections. Swages are often used in pairs. The lower half is called the BOTTOM SWAGE and is placed in the hardie hole of the anvil.

Sometimes you may want to punch or enlarge a hole in the metal you are working. For this job you use a set hammer with a PUNCH HEAD like (*E*) and (*F*). The square punch (*E*) is used to punch the initial hole, while the round punch (*F*) which is tapered, can be employed to enlarge the hole.

You make use of CHISEL-SHAPED set hammer heads, like those in figure 84 for CUTTING and NICKING your material. The cold-cutter chisel shaped

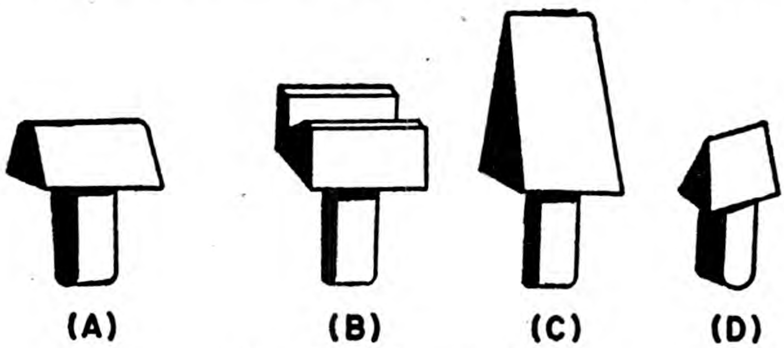


Figure 85.—Anvil tools.

head (*G*) is for use on cold iron or steel materials, while the hot-cutter, shown in (*H*) will cut hot, plastic metals.

Now come the tools which fit into that HARDIE HOLE in your anvil. They correspond in shape to

the set hammer heads and you can get results similar to those obtained with the corresponding types of set hammers.

The drawings in figure 85 which look like rural mail boxes, or bird houses, show a BOTTOM FULLER, (*A*), a BOTTOM SWAGE (*B*), a HOT HARDIE (*C*), and a COLD HARDIE (*D*). The bottom fuller, like the top fuller described earlier, is used for spreading or stretching metal. The shank of the fuller fits into the hardie hole. Bottom swages are often made with two or three grooves of different sizes in the same block, although the one shown in drawing (*B*) has only one groove. The hot hardie and cold hardie, shown in (*C*) and (*D*), correspond in shape to the hot and cold cutter types of set hammer heads and are used for the same purposes.

TONGS

Obviously, you can't handle hot pieces of iron with your bare hands. You need a number of TONGS.

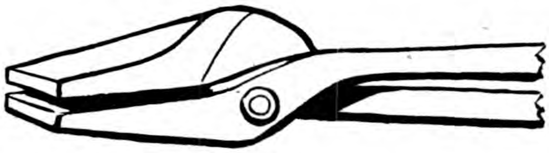
The first drawing, (*A*), shows a pair of FLAT TONGS, which you use to grasp flat pieces of work. Be sure, when you use these tongs on a flat piece that the jaws are parallel and have full-face bearing on the piece.

PICK-UP TONGS, like those in (*B*) are handy for picking up pieces of work and for holding small pieces while you are hammering or tempering.

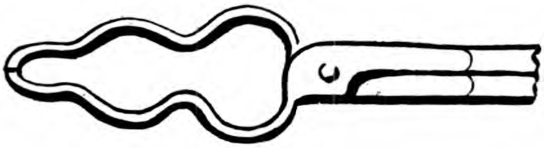
For holding bolts you need a tool like the BOLT TONGS in (*C*). The space or pocket, between the jaws is left to accommodate the head of the bolt while the semicircular shape of the jaws themselves allows you to get a firm grip on the shank of the bolt.

GAD TONGS, illustrated in (*D*) of figure 86, are much like bolt tongs. The jaws, however, instead

of being semicircular, are flat-faced so that they will hang onto flat or wedge-shaped pieces of work. The enlarged portion toward the rear of the jaws, like the pocket of bolt tongs, is designed to



(A)



(B)

(C)

(D)

Figure 86.—Tongs.

provide space for heads or shoulders that may have been formed on the ends of pieces being worked.

TECHNIQUES

For practically all anvil work, you handle the stock in your left hand and deliver blows with a hand hammer in your right hand. Your helper delivers the sledge-hammer blows and it is important that he watch your blows carefully in order to know the type of blow required. In other words, if your blow is heavy, his should be heavy. If your blows are light—his should be light.

HERE ARE SOME OF THE FUNDAMENTALS OF HAND FORGING.

Say you want to DRAW OUT a piece of metal—that is, you want to lengthen but not widen it. First heat the metal to a temperature as high as it can stand without injury. Then draw it out by pounding it over the horn rather than the face of the anvil. The reason for hammering your metal on the horn is that you thus use almost the entire energy of your blow in forcing the metal lengthwise. Very little of the energy of the blow goes into increasing the width. But if you put the metal on the face of the anvil to hammer it, almost 50 percent of the force is used up in uselessly widening the piece.

When you want to draw out or point ROUND STOCK, you must first forge it down square to the required size and then round it up using as few blows as possible. Look at figure 87. It shows the steps you use in drawing down a round bar from a larger to a smaller size.

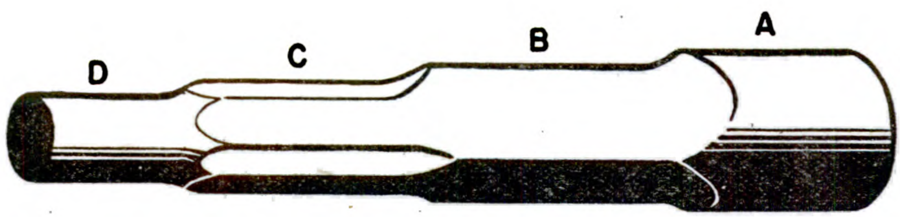


Figure 87.—Drawing down a round bar.

In (*A*) you see the bar at its original size. In (*B*) you see the first step—hammering it down square. Next you hammer this square shape into an octagonal shape, as in (*C*). And the octagon is finally rounded up as at (*D*). A piece is hammered square because if you didn't—if you tried to hammer the bar by pounding it round and round without the preliminary squaring—the bar would very likely split through the center.

Now suppose you want to increase either WIDTH or THICKNESS, or both, at the expense of the length. This operation is what blacksmiths call "UPSETTING." There are several ways to upset a piece of metal, depending largely upon the shape of the work. If the piece is short, you may stand it on end on the anvil and hammer directly down upon the upper end. (You have to keep the work straight of course, and catch any bends or kinks as soon as they appear.) If your piece to be upset is long, then you probably will swing it back and forth horizontally, thus upsetting it by ramming the end against the anvil.

Forging to shape by swaging is the method to use when SMOOTH AND ACCURATE SECTIONS are wanted. Swages, you remember, are tools used for finishing round and convex surfaces. Take the piece of stock and lay it on the bottom swage which has been stuck in the hardie hole of the anvil. Then hold the top swage over the piece of metal while your helper hammers down upon it.

Forgings are never exact duplicates because of a number of variables which enter into the forging operations. In hand forging, you can NEVER EXACTLY reproduce a given forging. Another point—in hot forging, you must constantly remember that the hot piece of metal is larger than it will be when it's cool.

FIGURING

The temperature at which forgings are finished under the hammer should be about 1,370° F. At this temperature, the color of the metal is bright red. When these same forgings are cold, their temperature will be from 60°–70° F.—a difference of some 1,300°. Iron expands about 0.00000662 of its length for every degree of temperature increased.

Thus, if the temperature of a 2-foot bar of cold iron is 70° F., and the temperature at red heat is 1,370° F., the increase in length because of expansion would be:

$(1{,}370-70)\times 0.00000662\times 2=0.0172$ foot, or 0.206 inch. This is nearly ¼ of an inch. Such expansion must be allowed for when you measure red hot forgings.

How Well Do You Know—

AIRCRAFT WELDING

QUIZ

CHAPTER 1

TOOLS OF THE TRADE

1. (*a*) What substance used in aircraft welding is self-explosive when kept under pressure greater than 15 psi?
   (*b*) What substance must be mixed with the above substance in order for it to burn at the temperature required to melt metals?
2. In the two-stage oxygen regulator,
   (*a*) What pressure forces the high-pressure valve tight against its seat IF the pressure adjusting screw is released before the cylinder valve is opened?
   (*b*) Why is this pressure unable to close the high-pressure valve as in (*a*) above if the pressure adjusting screw is not released before the cylinder valve is opened?
3. (*a*) What are the five major parts of the welding torch?
   (*b*) What device regulates the volumes of acetylene and oxygen entering the mixing head?
4. (*a*) How can oxygen-carrying hose be distinguished from acetylene-carrying hose?
   (*b*) How do welding equipment manufacturers insure you against attaching oxygen-carrying hose to the acetylene cylinder?
5. What is the procedure for blowing out the hose?
6. What are the four basic steps in setting up the welding apparatus?
7. (*a*) After the apparatus has been set up, for what possible defect should it be tested?
   (*b*) What is the test?
8. What two steps preparatory to welding involve decisions based on the thickness of the metal to be welded?
9. (*a*) What is the first step in lighting the welding torch?
   (*b*) How should the flame look at that stage?

10. Describe these types of torch flames briefly, under the headings shown:

	Oxygen-Acetylene Proportion	Appearance	Effect On Metals
(*a*) Neutral.			
(*b*) Oxidizing			
(*c*) Carburizing			

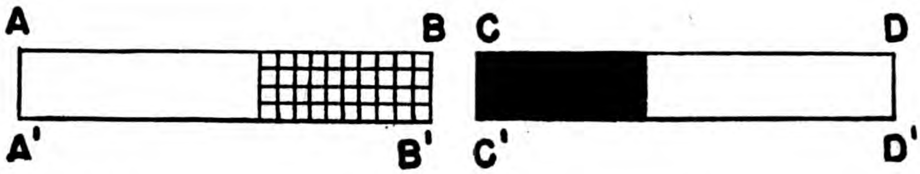
11. (*a*) What effect does a "harsh" flame have on metal?
(*b*) What causes a "harsh" flame?
12. (*a*) What is the remedy for torch flame "popping"?
(*b*) What are two other operating difficulties common to torch flames?
13. In draining the regulators and lines when you close down your welding unit, what must you do in order to avoid a flashback?

CHAPTER 2

USING THE EQUIPMENT

1. (*a*) In which welding method is the filler rod added between the flame and the finished weld?
(*b*) In the other method, how is the torch tipped?
2. (*a*) What is the relation between the thickness of the metal to be welded, and the size of the filler rod you select?
(*b*) What other characteristic of the base metal will influence your selection? Why?
3. (*a*) What are two characteristics of the vertical welding position which do not apply to any of the other positions?
(*b*) What is the difference between the position of the metal parts in horizontal and in flat welding?
(*c*) What precaution should be taken in horizontal welding, to keep molten metal from running to the lower side of the seam?
(*d*) Name the position not referred to in any of the above questions.

4. (*a*) What are the four basic steps in preparing a joint for welding?
   (*b*) Which step may be omitted if the base metal is relatively thin?
5.



   (*a*) If these two strips of metal are welded to make a continuous line of overall length equal to *A–D*, what kind of joint has been used?
   (*b*) If the strips are welded so that the entire shaded portion of strip *CD* rests upon the checked portion of strip *AB*, what type joint has been used?
   (*c*) If strip *AB* is up-ended and welded so that *Bb* rests upon and in the center of *CD*'s unshaded portion, what type joint has been used?
   (*d*) If the strips are welded so that angle *DBA* is equal to 90°, what kind of joint has been used?
6. (*a*) What is a fillet weld?
   (*b*) Which of the general types of joints do (does) not require a fillet weld?
7. Refer to your ANSWERS to question No. 5, parts:
   (*a*) How many different varieties of this joint are used in welding?
   (*b*) Which of the three varieties of this joint could not be formed from these two strips as shown?
   (*c*) If each strip were ¼″ thick, what special treatment of the end(s) would be required?
   (*d*) If this joint were to carry an exceedingly heavy load, which variety would be used?
8. Refer to the two strips of metal illustrated for question No. 5. Assume each strip is ¼″ thick, and a butt joint is to be used.

(*a*) Approximately how wide should the top reinforcement be, from toe to toe?
(*b*) Approximately how far should the bead be built up?
(*c*) How far should the weld metal be fused into the sides of the joint?
(*d*) How far should the weld metal extend above the surface of the base metal?
(*e*) If the strips were to be welded into a TEE joint, how far should the bead be built up?

9. Refer to the two strips of metal illustrated for question No. 5.
(*a*) If each strip were ¼″ thick and 1′ long, how much space should you allow between the ends at which you begin welding? How much between the other ends?
(*b*) What is the welder's name for this method of spacing?
(*c*) There are three other steps frequently used to minimize harmful effects of welding heat on metal. Which of these steps is helpful because it encourages uniform expansion and contraction of the metal in welding?
(*d*) What are the other steps?

10. (*a*) What is the most frequent cause of flashbacks?
(*b*) What must you use to light your welding torch?
(*c*) What should your position be when you open a cylinder valve?
(*d*) What are two essential items of dress for welders?
(*e*) In what position must acetylene cylinders be stood?

CHAPTER 3

TECHNIQUE FOR FERROUS METALS

1. (*a*) Why should metal never be welded after it has been cold-worked?
(*b*) What other treatments make metal unsuitable for welding?

2. Which of the ferrous metals discussed in this chapter should be preheated before welding?

3. Why is flux used in welding?
4. Which of the ferrous metals in chapter 3 require(s) the use of flux during welding?
5. (*a*) Which of the metals in chapter 3 requires the use of a filler rod only when the pieces to be welded are 1/16″ or thicker?
   (*b*) Which require a rod which will return to the metal certain elements tending to burn out during welding?
   (*c*) What type filler rod should be used with the other metals in this chapter?
6. (*a*) On what general basis does a welder decide what size torch tip to use for a welding job?
   (*b*) In selecting a torch tip for welding stainless steel, what characteristic of that metal is also considered?
   (*c*) How, then, should torch tips used in welding stainless steel compare in size with tips used for plain steel?
   (*d*) How should torch tips used in welding gray cast iron compare in size with tips used for plain steel?
7. (*a*) Which metals in chapter 3 require a neutral welding flame?
   (*b*) What type flame do the other metals in this chapter require?
   (*c*) What is a good way to adjust a neutral flame?
   (*d*) How can you see that a flame is slightly carburizing?
8. In welding stainless steel—
   (*a*) Where should you hold your filler rod?
   (*b*) When should the metal be "puddled"? Why?
   (*c*) Why is it so important to avoid retracing a weld?
   (*d*) If you start a 2-foot weld on the top side, at what point should you start welding it from the bottom?
9. What are the rules for SPEED of welding and cooling cast iron?
10. Describe the general procedure for welding—
    (*a*) Low, medium, and high carbon steel.
    (*b*) Gray cast iron.

CHAPTER 4

TECHNIQUE FOR NONFERROUS METALS

1. What type of welding flame does each of these metals require?
   (*a*) Aluminum alloys.
   (*b*) Magnesium alloys.
   (*c*) Inconel and Monel.
2. (*a*) Why should torch tips for welding aluminum alloys be slightly larger than for steel of similar thickness?
   (*b*) What other metals discussed in chapter 4 sometimes take a welding tip larger than for steel?
3. What is the MAXIMUM temperature for preheating aluminum alloys?
4. (*a*) Why is it necessary to use flux in welding sheet aluminum alloys?
   (*b*) How is flux removed after welding sheet aluminum?
   (*c*) How is flux removed from magnesium alloys after welding?
   (*d*) Explain the connection between the importance of removing flux from welded magnesium alloys, and the limited number of types of joints that can be made with this metal.
5. What two signs tell you when sheet aluminum has reached its melting point?
6. Why must you work fast when welding aluminum?
7. Describe the general procedure for welding aluminum.
8. Using a neutral welding flame is one way of protecting magnesium alloys against oxidation during welding. What is another way?
9. What is the difference between the methods of spacing open and closed butt joints on Inconel?
10. Why must fillet welds on Inconel be made with particular care?
11. Why should Inconel welding be done in a well-ventilated place?

CHAPTER 5

TUBING REPAIR

1. Where on an airplane are you apt to find chrome-moly?
2. In welding this metal,
   (*a*) What kind of filler rod should you use?
   (*b*) What kind of torch flame should you use?
   (*c*) What kind of flux should you use?
3. What characteristic of this metal makes it particularly important to avoid over-heating at or near an edge?
4. Under what circumstances should welds on aircraft tubing be filed down?
5. (*a*) What is the first step in anticorrosion treatment for steel tubing which has been repaired by welding?
   (*b*) What intermediate step is required only for seaplanes?
   (*c*) What is the final step?
6. Explain the meaning of "drawing off," and the value of this process.
7. (*a*) In what two shapes may the ends of aircraft tubing be cut for splicing?
   (*b*) With what instrument must they be cut?
   (*c*) What portion of a section of tubing must NOT be cut for splicing?
   (*d*) How many replacement tubes may be spliced into any one section?
8. (*a*) Which of the general methods of tube repair by splicing cannot be used if there are any fittings attached to the original tubing?
   (*b*) If there are fittings attached, which type of repair must be used?
9. When you repair aircraft tubing by the inner reinforcing sleeve method,
   (*a*) What size replacement tubing should you select?
   (*b* Why should you cut the replacement ¼″ shorter than the section it is to replace?
   (*c*) What size reinforcing sleeve should you select?

(*d*) How should you support the structure while you do the splicing?

(*e*) What marks do you use in centering the reinforcing sleeve beneath the joint?

(*f*) Explain how you locate and drill the holes through which the welding or brazing wire is to be pulled.

(*g*) Fill in the steps not discussed in (*a*) to (*f*) above.

10. When you repair aircraft tubing by the outer reinforcing sleeve method,

(*a*) What size replacement tubing should you select?

(*b*) How much shorter than the removed section should the replacement be?

(*c*) What size reinforcing sleeve should you select?

11. When you repair aircraft tubing by using a larger diameter replacement tube,

(*a*) How long should the stub ends be after the damaged section is cut out?

(*b*) What size replacement tubing should you use?

(*c*) How long a piece of replacement tubing should you use?

12. Which of these general methods of aircraft tubing repair by splicing involves the greatest danger of heat distortion? Why?

CHAPTER 6

CUTTING

1. What effect (on metal) so carefully avoided in oxyacetylene WELDING is utilized in oxyacetylene CUTTING?
2. What is the difference in composition between the heating flame and the flame which actually cuts the metal?
3. Explain the difference between the ways in which gases emerge from a welding torch tip and a cutting torch tip.
4. By what device is the oxygen jet regulated?
5. Why should you keep a clear space of 30–40 feet around you during the oxyacetylene cutting process?
6. How should you protect combustible materials that cannot be cleared away during the process?

CHAPTER 7

BRAZING AND SOLDERING

1. What are the two principal differences between welding and soldering?
2. What are the two general types of hard soldering discussed in this chapter?
3. (*a*) Which hard-soldering method uses a copper-tin alloy solder?
   (*b*) What metal is brazed with a copper-zinc alloy solder?
4. Why should bronze welding never be used in repairing an exhaust manifold?
5. (*a*) What will happen if you overheat the base metal, in bronze welding?
   (*b*) What will happen if you do not get the metal hot enough?
6. What kind of welding flame is required for
   (*a*) Bronze welding?
   (*b*) Welding brass?
7. When and how should the edges of a joint on brass be beveled before welding?
8. What should be the relation between the melting points of the base metal and the filler rod, in welding brass?
9. (*a*) What ingredients can you mix to use for flux on a silver soldering job, if there is no prepared flux available?
   (*b*) How does the action of a prepared flux on the metal tell you when to begin applying the silver solder?
10. For silver-soldered lap joints in sheet and small diameter tubing, how much lap should there be?
11. (*a*) What type of soldering discussed in this chapter is used only on very minor repair jobs?
    (*b*) Why should it never be used as the sole means of attachment of structural members?
12. (*a*) What instrument supplies the heat for soft-soldering?

(b) What is meant by "tinning" this instrument?
(c) Describe the "tinning" procedure briefly.

13. (a) When the priming pan of gasoline blowtorch is partly full, how do you proceed?
(b) Where on the blowtorch is the soldering copper held for heating?

14. What name is given to the soldering method in which two surfaces are tinned, and then held together and heated with soldering copper or blowtorch until the solder melts and runs out?

15. (a) What are the three ingredients of the solution recommended for removing flux from nonferrous metal?
(b) What treatment will remove flux from ferrous metals?
(c) What should you do to any metal after treating it to remove flux?

CHAPTER 8

BLACKSMITHING

1. What is meant by "blacksmithing"?
2. Mention four steps or precautions you must take in order to keep oxygen from hot metal during the blacksmithing process.
3. What is meant by the "peen" of a hammer?
4. Which hammer is used for stretching metal
   (a) Sidewise?
   (b) In length and width?
   (c) Lengthwise only?
5. (a) What are the two principal uses of set hammers?
   (b) Which of the set hammer heads has an effect like that of the long-peen hammer?
6. What anvil tools are similar in shape and use to the hot- and cold-cutter chisel-shaped set hammer heads?
7. In drawing out a square piece of metal—
   (a) What is the first step?
   (b) On what part of the anvil is it pounded?

8. Why must round stock be forged down square before being drawn out or pointed?
9. (*a*) What is meant by "upsetting" a piece of metal?
   (*b*) If the piece is short, how may it be upset?
10. For surfaces of what shape is swaging used?
11. How much must you expect a 3-foot piece of iron to expand when it is heated from 70° F. to 1670° F.?

ANSWERS TO QUIZ

CHAPTER 1

TOOLS OF THE TRADE

1. (*a*) Acetylene.
   (*b*) Oxygen.
2. (*a*) The pressure exerted by oxygen flowing, from the cylinder, against the high-pressure valve.
   (*b*) Because the pressure (exerted by incoming oxygen) tending to close the high-pressure valve is opposed by pressure (exerted by the diaphragm and connecting arm as long as the tightened pressure adjusting screw compresses the adjusting spring). This opposing pressure tends to hold the valve away from its seat.
3. (*a*) Brass handle.
   Oxygen and acetylene tubes within the handle.
   Torch head.
   Mixing head.
   Tips.
   (*b*) Needle valve.
4. (*a*) Color: Oxygen hose is green or black; acetylene hose is red or maroon.
   Name of gas is usually printed on hose.
   (*b*) By using only left-hand thread nuts on acetylene hose and tank connections, and only right-hand thread nuts on oxygen-hose connections.
5. Open cylinder valve.
   Turn pressure-adjusting screw clockwise until low-pressure gage shows 5 pounds per square inch.
   Release pressure-adjusting screw when hose has been cleaned out.

6. Fasten cylinders.
   Crack cylinder valves.
   Connect regulators to cylinders.
   Attach hoses to regulators and to welding torch.
7. (*a*) Leaks.
   (*b*) Soap suds brushed over the connections.
8. Selecting welding tips of correct size.
   Setting working pressure.
9. (*a*) Open the acetylene needle valve on the torch enough to allow a little gas to escape.
   (*b*) Large, yellowish red, smoky on the outer edges.

10. Oxygen-Acetylene Proportion	Appearance	Effect on Metals
(*a*) Neutral—One-to-one	Well-defined white cone near tip, surrounded by faintly glowing bluish cone 1/16″ to 3/4″ long.	Melts metal without changing its properties; leaves metal clear and clean.
(*b*) Oxidizing—Excess of oxygen	Inner cone shorter and more pointed, and almost purple instead of white.	Burns metal; much foaming and sparking; weld is porous and brittle.
(*c*) Carburizing—Excess of acetylene.	Three flame zones: White inner cone merges into intermediate white cone with feathery edge; bluish outer cone remains.	Increases carbon content; molten metal boils and loses clearness; weld is hard and brittle.

11. (*a*) It destroys the weld puddle and causes the metal to splatter around the edges of the puddle; metal will not fuse easily.
    (*b*) Excessive pressure of gases at welding tip.
12. (*a*) Open both needle valves farther, so that more gas can flow to the tip.
    (*b*) Flame backfiring.
    Flashback.
13. Drain the acetylene line first, then drain the oxygen line.

CHAPTER 2

USING THE EQUIPMENT

1. (*a*) Backhand.
   (*b*) Sideways, at an angle of 50° or 60° to the surface of the work, with the flame pointed toward the base metal.
2. (*a*) The diameter of the filler rod used should equal the thickness of the metal to be welded.
   (*b*) Chemical composition. The filler rod must be of chemically "friendly" composition.
3. (*a*) Vertical seam.
   Only forehand method may be used.
   (*b*) In horizontal welding the parts are tipped to an angle of 45° or more, whereas in flat welding they are tipped to an angle of less than 45°.
   (*c*) Flame should be pointed slightly upward.
   (*d*) Overhead.
4. (*a*) Clean surfaces.
   Bevel edges, if necessary.
   Arrange parts in correct welding position.
   Devise correct support for parts.
   (*b*) Beveling edges.
5. (*a*) Butt.
   (*b*) Lap.
   (*c*) Tee.
   (*d*) Corner.
6. (*a*) Any weld joining two parts at right angles to each other.
   (*b*) Butt joint.
7. (*a*) Three.
   (*b*) "Joggled." (Offset.)
   (*c*) The end (*Bb*) of the vertical part (*AB*) should be beveled on one side.
   (*d*) Open.
8. (*a*) 3/4″ to 1 1/4″ wide.
   (*b*) To a total thickness measuring from 5/16″ to 3/8″.
   (*c*) 100%.
   (*d*) At least 1/16″ to 1/8″.

(*e*) To a total thickness (through the throat) of at least ¼″.

9. (*a*) 0″.¼″.
(*b*) Tapering.
(*c*) Preheating entire piece.
(*d*) Use clamps, jigs and chill bars.
Rapid welding.

10. (*a*) Leaks between the oxygen and acetylene inlet openings leading to the mixing head.
(*b*) Sparklighter.
(*c*) BESIDE the regulator.
(*d*) Goggles.
Gauntlet gloves.
(*e*) With their valve ends up.

CHAPTER 3

TECHNIQUE FOR FERROUS METALS

1. (*a*) Because the heat of the welding flame will destroy any strength the metal gained from the cold-working process.
(*b*) Heat-treating. (Unless facilities for reheat-treating are available.)
Brazing.
Soldering.
2. Gray cast iron.
3. To remove oxides or to prevent them from forming.
4. Stainless steel.
Gray cast iron.
5. (*a*) Stainless steel.
(*b*) Gray cast iron.
Stainless steel.
(*c*) Low and medium carbon steel: Low carbon steel OR soft iron containing a small percentage of vanadium.
High carbon steel: High carbon.
Wrought iron: Wrought iron OR low carbon steel.
6. (*a*) The thickness of the metal pieces to be welded.
(*b*) Poor heat conduction.

(c) A tip to be used in welding stainless steel should be one or two sizes smaller than one which would be used for plain steel of the same thickness.

(d) They should be one size larger than for plain steel of the same thickness.

7. (a) All except stainless steel.

(b) Stainless steel requires a very slightly carburizing flame.

(c) Open the acetylene valve until a feather appears around the inner cone. Then slowly close the valve until the feather JUST vanishes.

(d) Feathers about 1/16″ long are visible around the inner cone.

8. (a) Ahead of the welding flame.

(b) Never. Puddling stirs in oxygen.

(c) Because alternate heating and cooling is bad for steel.

(d) None. Stainless steel should be welded from one side entirely.

9. Weld as fast as possible.
Cool as slowly as possible.

10. (a) Check your answer against pages 63–67.

(b) Check your answer against pages 81–84.

CHAPTER 4

TECHNIQUE FOR NONFERROUS METALS

1. (a) Neutral, or slightly carburizing.

(b) Neutral.

(c) Carburizing.

2. (a) To offset the heat-conducting property of aluminum alloys, which make it difficult to obtain the necessary heat concentration.

(b) Inconel and Monel.

3. 800° F.

4. (a) To break through and carry off the oxide coating on the sheet so that filler metal can flow into clean base metal.

(b) By washing the piece in hot water or a sulphuric acid solution.

(c) By scrubbing, soaking in hot water, soaking in a citric acid or chrome-pickle solution, and rinsing.

(d) The number of joints that can be made on this metal is limited to types which provide no corners, pockets, etc., from which the flux might NOT be REMOVED. Thus, the butt weld is the only type which can be made on this metal.

5. The metal will have a light gray color when viewed through light blue glasses.

   The metal will feel soft and elastic when touched lightly with the filler rod.
6. Because the melting point of aluminum is so low that holding the welding flame too long in one place will burn holes through the metal.
7. Check your answer against pages 88–95.
8. Keeping the weld area bathed with the outer envelope of the welding flame.
9. Edges to be joined in an open type butt joint are spaced at a slight taper; whereas edges to be joined in the closed type are set up parallel, with space between them equal to the metal thickness.
10. Because Inconel is weak and brittle when it hardens after being melted, and fillet welds are apt to crack or pull out.
11. Because the fumes from the melting flux are poisonous.

CHAPTER 5

TUBING REPAIR

1. Fuselage.

   Engine mount.
2. (a) Low carbon steel.

   (b) Neutral. Outer envelope of flame should never be more than 1/8″ long.

   (c) No flux is needed.
3. Chrome-moly is extremely weak at high temperatures.
4. Only when further welding is to be done on that section.

5. (*a*) Sand-blast all outside surfaces.
   (*b*) Metal-spread.
   (*c*) Apply coating of zinc-chromate primer.
6. "Drawing off" means heating the entire part uniformly to a temperature between 1150° and 1200° F., and then permitting it to cool slowly. It relieves expansion and contraction stresses on alloy steel parts after welding.
7. (*a*) Diagonal.
   Fishmouth.
   (*b*) Hacksaw.
   (*c*) The middle third of the section.
   (*d*) One.
8. (*a*) External replacement tube of diameter larger than original tubing.
   (*b*) Reinforcing sleeves over or under replacement tube of diameter equal to original tubing.
9. (*a*) The same diameter and wall thickness as the original (damaged) tubing.
   (*b*) To allow you to weld replacement tube to reinforcing sleeve at each end.
   (*c*) The same wall thickness as the original tubing, and outside diameter equal to the inside diameter of the original tubing.
   (*d*) By a brace arrangement.
   (*e*) The center mark on the diagonal cut of each original tube stub end, and the center mark around each reinforcing sleeve.
   (*f*) Points are located and center punched 2¼ tube diameters from the nearest end of each diagonal cut on the original tubing. Drilling is started at a 90° angle to the surface of the tubing and finished at a 30° angle, slanted toward the cut.
   (*g*) Check your answer against pages 131–136.
10. (*a*) The same diameter and wall thickness as the original tubing.
    (*b*) Not more than $1/16''$.
    (*c*) Inside diameter equal to the outside diameter of the original tubing.

11. (*a*) The short stub should be at least 2½ tube diameters, and the long stub should be at least 4½ tube diameters.
    (*b*) Inside diameter equal to the outside diameter of the original tubing.
    (*c*) Long enough so that each end extends at least 1¼ tube diameters past the ends of the original tube.
12. Outside sleeve reinforcement. Because this method requires the greatest amount of welding.

CHAPTER 6

CUTTING

1. Oxidation.
2. The heating flame is composed of a one-to-one mixture of oxygen and acetylene; whereas the "cutting" flame is pure oxygen.
3. From the welding torch tip one flame emerges, composed of a mixture of oxygen and acetylene.
   From the cutting torch tip one jet of pure oxygen emerges from a large central hole and an oxygen-acetylene mixture emerges from several holes arranged in a circle around the oxygen hole.
4. A triggerlike valve.
5. Because hot slag will roll along the floor for a considerable distance.
6. Cover them with sheet metal guards or asbestos blankets.

CHAPTER 7

BRAZING AND SOLDERING

1. In soldering, a filler metal entirely different from the base metal(s) may be used; whereas in welding filler metal and base metal must be chemically matched.
   In soldering, the metal is not melted, whereas in welding it is.
2. Brazing.
   Silver soldering.
3. (*a*) Bronze welding (brazing).
   (*b*) Brass.

4. Because bronze loses its strength at temperatures of 500° F. or more and should never be used for brazing metal which will be subjected to high temperatures.
5. (*a*) The bronze filler metal will boil when added, its low melting point alloys will burn out, and it will be porous and brittle.
   (*b*) The bronze will not flow smoothly.
6. (*a*) Neutral.
   (*b*) Oxidizing.
7. When the piece to be welded (brazed) is thick the edges should be beveled, by filing or some other mechanical method.
8. The melting point of the filler rod should be slightly lower than that of the brass.
9. (*a*) Borax and boric acid.
   (*b*) When the flux starts to flow freely it is time to apply the solder.
10. At least four to six times the metal thickness.
11. (*a*) Soft-soldering.
    (*b*) Because it is not strong enough to withstand heavy loads.
12. (*a*) Soldering copper.
    (*b*) Cleaning and applying copper to it.
    (*c*) Heat soldering copper to bright red, clean point by filing, clean point by dipping it into cleaning compound, and apply solder; or heat and file, and then rub over block of sal ammoniac on which a few drops of solder have been melted.
13. (*a*) Close the gasoline valve, light the gasoline in the pan, open th e valve again slightly when the flame has heated up the nozzle, and adjust the flame.
    (*b*) On the holders attached to the top of the blow-torch nozzle.
14. Sweating.
15. (*a*) Sulfuric acid, sodium bichromate, water.
    (*b*) Boiling for 30 minutes in a 10–15 percent solution of caustic soda.
    (*c*) Rinse it thoroughly in clean water.

CHAPTER 8

BLACKSMITHING

1. Heating iron or steel, by forge or welding torch, until it can be shaped by hammering or pounding.
2. Control amount of air supplied to fire through tuyere.
   Use small pieces of coke.
   Place parts to be heated according to approved method.
   Never use green coal to cover the parts to be heated.
3. The back face: the shape of the top, or back, surface of the head, opposite the working surface (face).
4. (*a*) Long-peen. (Straight-peen)
   (*b*) Ball-peen.
   (*c*) Cross-peen.
5. (*a*) To position a blow delivered by another hammer or sledge.
   To give some part of the work a definite form which cannot be obtained by hammering directly upon the work.
   (*b*) Fuller.
6. Hot and cold hardies.
7. (*a*) Heat the metal to a temperature as high as it can stand without injury.
   (*b*) Horn.
8. Because hammering the bar without preliminary squaring would probably split it through the center.
9. (*a*) Increasing its width, thickness, or both, at the expense of its length.
   (*b*) By hammering directly down upon the upper end of the metal as it stands on end on the anvil.
10. Round and convex.
11. 0.031776 foot $(0.00000662 \times (1670 - 70) \times 3$ feet).